VORTEX

DYNAMIC BALANCER AND VIBRATION ANALYSER

USER MANUAL V5.0

DYNEX HOBBY

SAFETY FIRST

High speed rotors contain enough energy to cause damage to people and property. Manufacturer’s safety precautions MUST be adhered to during testing and operation of devices.

Safety goggles must be worn during testing and operation of devices. High speed rotors can expel high velocity debris during an adverse event.

WARNING!

- ✓ Never stand in front of or alongside a spinning rotor. Stand behind at a safe distance.
- ✓ Ensure bystanders are well away from the test article at a safe distance.
- ✓ NEVER run a rotor at full speed when balancing. Mounting cradles are not designed to restrain running devices at operational speeds.
- ✓ Run devices at the slowest possible speeds to avoid injury.
- ✓ Do not leave loose items nearby that can be caught by a spinning rotor.
- ✓ Secure all loose cables to prevent being caught in moving parts.
- ✓ Always stop running devices before working on them.
- ✓ Never place a limb in front of a rotor to stop it or slow it down.
- ✓ Fasten devices in secure mounts when operating at full speed. Follow the manufacturer’s instructions for correct device operation.
- ✓ **Strobe** light may cause seizures.
- ✓ Vortex was **not** designed for full size vehicles or industrial applications.

Before you begin

Your safety is your own responsibility, including proper use of equipment and safety gear, and determining whether you have adequate skill and experience. Improper use of modeling gear is dangerous, unless used properly and with adequate precautions, including safety gear. Some illustrative photos do not depict safety precautions or equipment, in order to show operating instructions more clearly. These products are not intended for use by children. These products are intended for radio control model applications and should never be used on industrial equipment.

Use of our products and content on DynexHobby.com is at your own risk. It is your responsibility to make sure that your activities comply with applicable laws, including copyright. The United States Fire Administration (USFA) has a guide and many simple steps you can take to prevent the loss of life and property resulting from electrical fires.

VORTEX SYSTEM OVERVIEW

Introduction

Vortex is a combined dynamic balancer and vibration analyzer for hobbyist. It is capable of balancing rotors and shaft assemblies to reduce wear and improve performance. The vortex system can operate as a stand-alone device or it can be connected to a PC for advanced analysis. This manual outlines the Vortex system and leads the operator through examples on its application.

The Vortex system consists of the following parts. The analyzer or “black box” is the central processing unit. It collects and analyses vibration signals for dynamic balancing and spectrum analysis. Vortex is connected to a PC via the “microphone” port using a 3.5mm stereo cable.

The system includes an accelerometer for measuring the acceleration levels of vibration. An infra-red detector and strobe light is also supplied for synchronizing the location of corrective weights required for balancing.

Vortex Analyzer

3.5mm Stereo Cable

Accelerometer

IR Sensor

Strobe Light

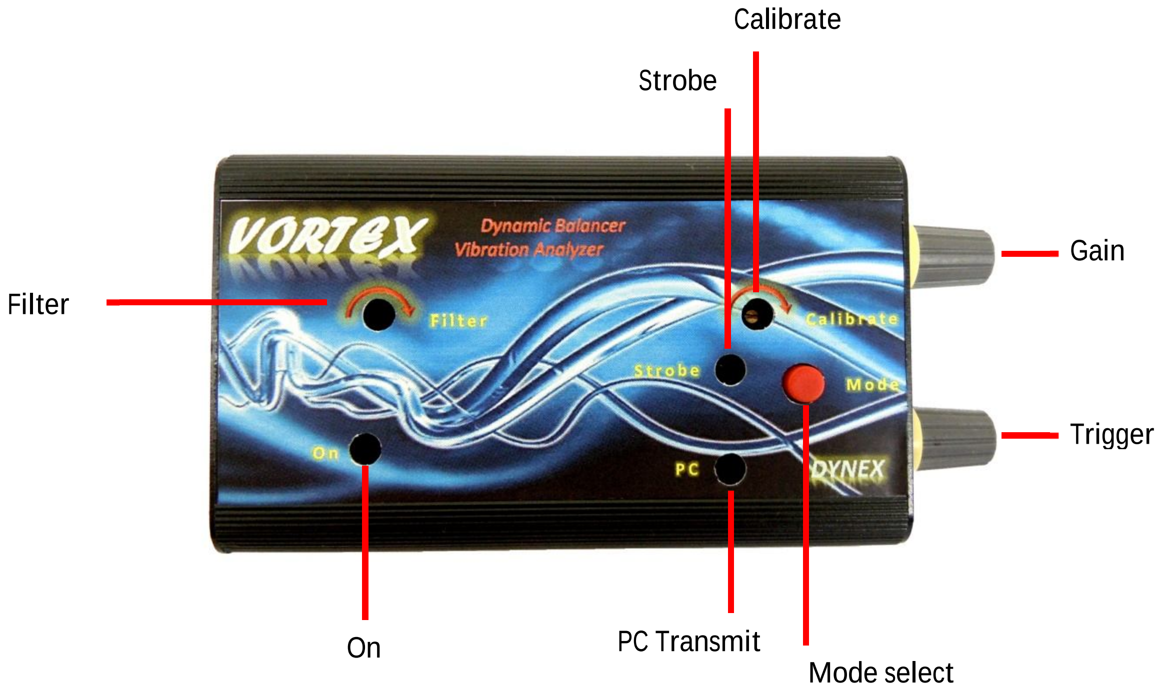
SPECIFICATIONS

Item	Quantity
Vortex	• 9~12 VDC power supply • Anodized aluminum case • Dimensions (outer): 24mm(0.94")(H)x66mm(2.6")(W)x110mm(4.33")(L)
IR Detector	• Dimensions: 0.3" x 0.5" x 0.1" • Operating voltage: 5.0V • Supply current: 25mA • Output format: analog voltage • Optimal sensing distance: 0.125" (3 mm) • Maximum recommended sensing distance: 0.25" (6 mm)

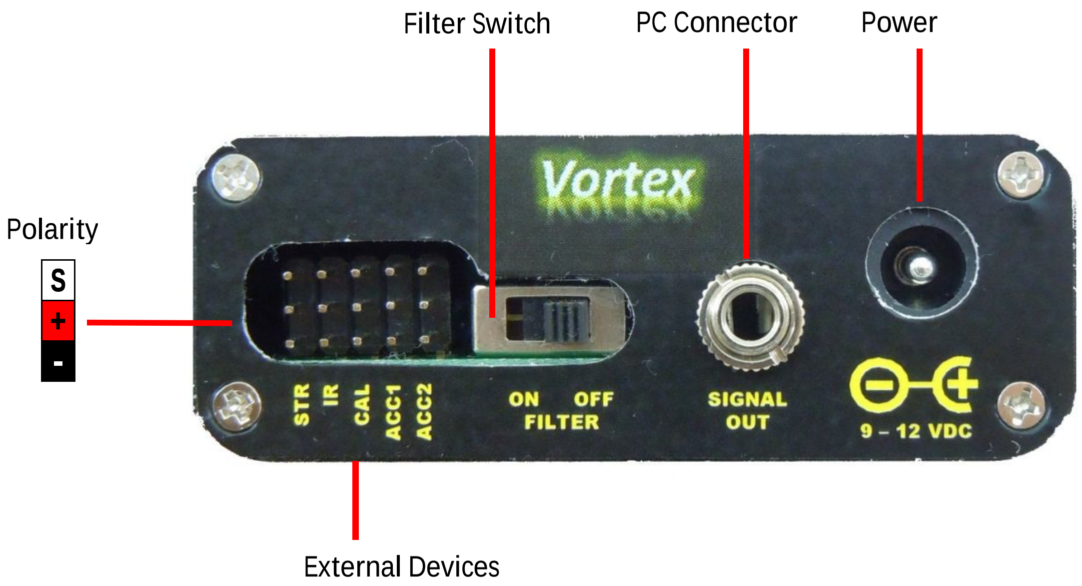
Accelerometer (ACC1)	• Range: +/- 3g
	• Sensitivity: 300 mV/g
	• Small, low-profile package
	• 1.8 V to 3.6 V operating range
	• 10,000g shock survival
	• Excellent temperature stability
	• Output Type: Analog
	• Typical Bandwidth (kHz):
	  o 1.5kHz without capacitor
	  o 50 Hz with capacitor installed
	• Noise Density (µg/rtHz): 300

STROBE LIGHT	• Intensity 25000~35000 MCD • Viewing angle 25 degrees

VORTEX FEATURES



Item	Function
On	Light illuminates when power is applied to Vortex
PC Transmit	Light illuminates when Vortex transmits data to PC. Activated by **mode** button.
Strobe	Light illuminates when Vortex is in Strobe Mode. Activated by **mode** button.
Calibrate	Rotate clockwise/anticlockwise to zero accelerometer
Mode Select	Press to active PC or Strobe modes. When pressed, the button remains locked. Press again to unlock mode.
Trigger	Rotate right to increase strobe sensitivity. Rotate left to decrease sensitivity.
Gain	Rotate left to increase accelerometer sensitivity. Rotate right to decrease sensitivity. *Note: Do not change gain setting between test runs.*
Filter	Rotate right to increase signal filtering. Rotate left to decrease filtering.



Item	Function
Power	DC power supply. Recommended supply of 9 ~12 VDC. Center pin is "+"
PC Connector	Stereo cable socket. This connects to PC sound card at "microphone input"
Filter switch	Turn signal filtering on or off.
STR	Connection for LED Strobe Light
IR	Connection for infra-red reference detector
CAL	Connection for accelerometer calibration
ACC1	Connection for accelerometer "ACC1". For accelerometers that use 3V power supplies. ACC1 is supplied in the standard kit.
ACC2	Connection for accelerometer "ACC2". For accelerometers that use 5V power supplies. ***This port currently not used.***
Polarity	Black wire of connector always faces downward.

CONNECTING VORTEX

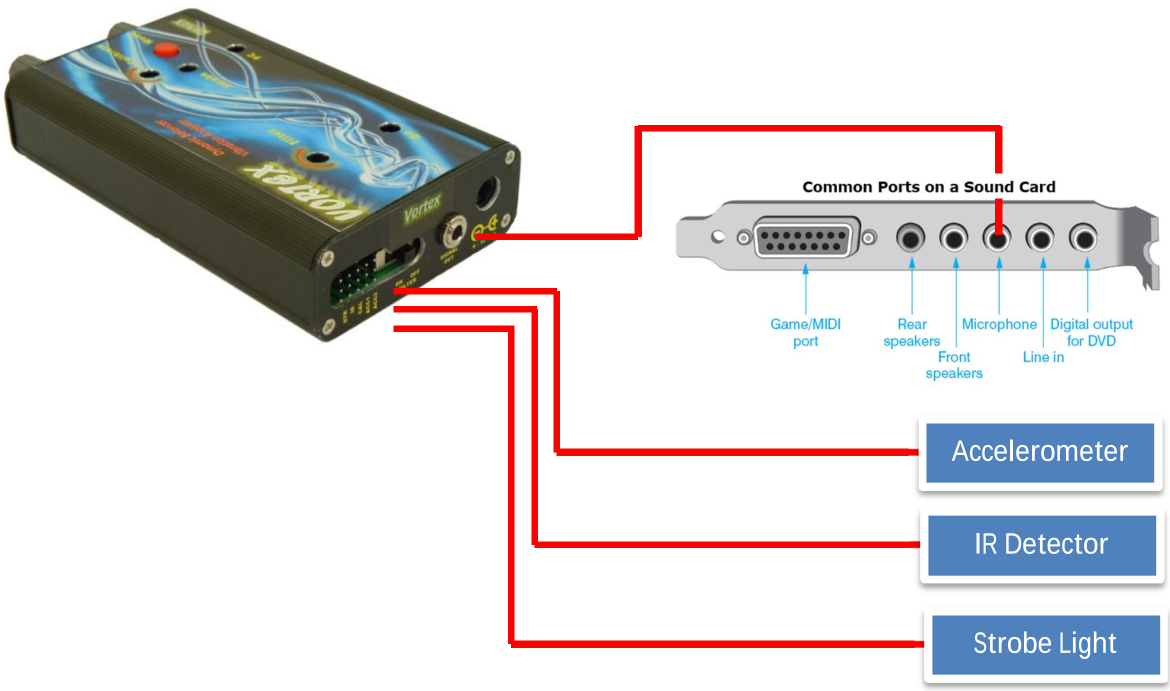
The diagram below illustrates the typical connections for the Vortex system.

STEREO CABLE: Vortex communicates to a PC via 3.5mm stereo cable which is connected to the microphone input of the PC sound card. The stereo cable can be connected at any time, however the cable must be connected when performing balancing or vibration spectrum analysis. The cable is not required for the "Strobe Balancing Method".

ACCELEROMETER: Must be connected to ACC1. Port ACC2 is not currently used. ACC2 is reserved for future development of sensors. **Warning! Do not connect the accelerometer to ACC2 as this could damage the sensor.**

IR SENSOR: Must be connected to the IR port. The IR Sensor is used during balancing only. It is not required for the "Strobe Balancing Method".

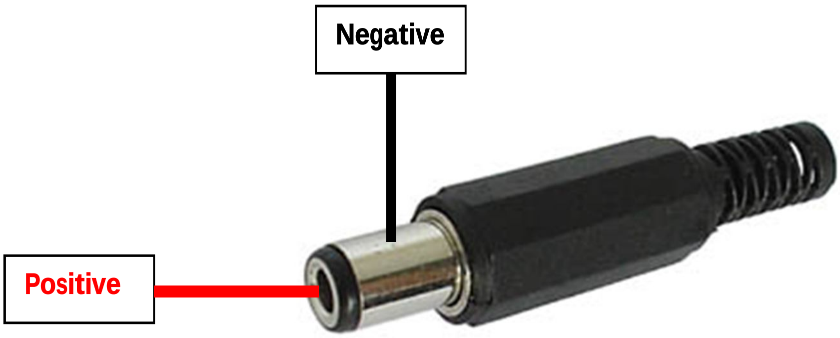
STROBE LIGHT: Only required for the "Strobe Balancing Method".



POWERING VORTEX

Vortex is designed to be powered by a 9~12 V DC source (9VDC preferred). Do not use a mains power pack as tests have shown some packs can induce noise in the system. A battery such as a Lithium Polymer or Lithium Ion is recommended as this creates a noise free power source. Please follow manufacturer's instructions on proper handling of batteries.

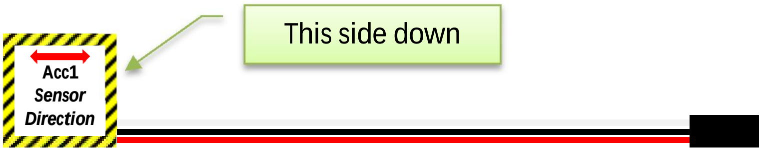
DC POWER PLUG CONNECTION



INSTALLING THE ACCELEROMTER

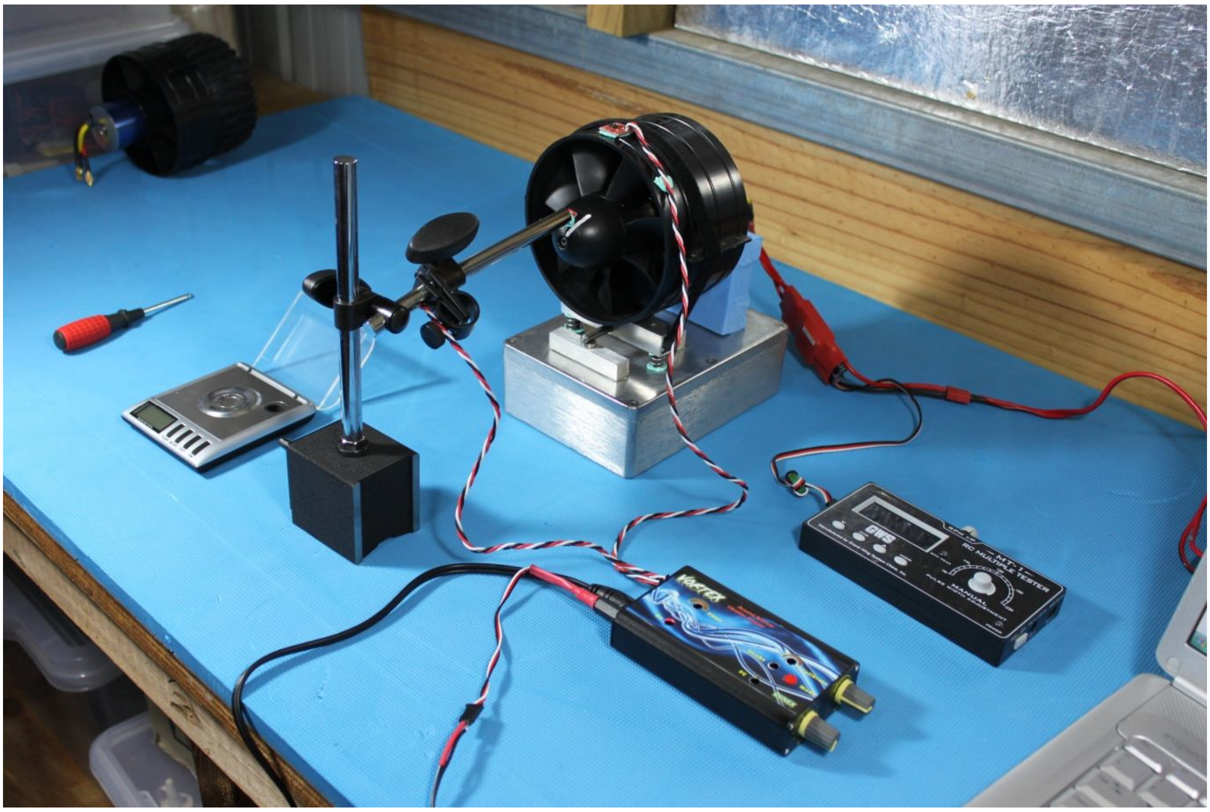
Install the accelerometer on the rotor suspension system. It is best to install it in a horizontal position. The accelerometer can be positioned at any angle as desired, however the full scale deflection can be limited.

The side that has the yellow label is positioned downward and glued to the device under test. Experiments have shown that attaching the accelerometer using “Blu-tack” is adequate.



CAUTION!

1. *Secure any loose cables to the device using “Blu-tack” or tape. This will prevent cables from getting caught in the spinning rotor and reduces mechanical noise during testing.*
2. *Do not install any part of Vortex to moving or rotating parts.*

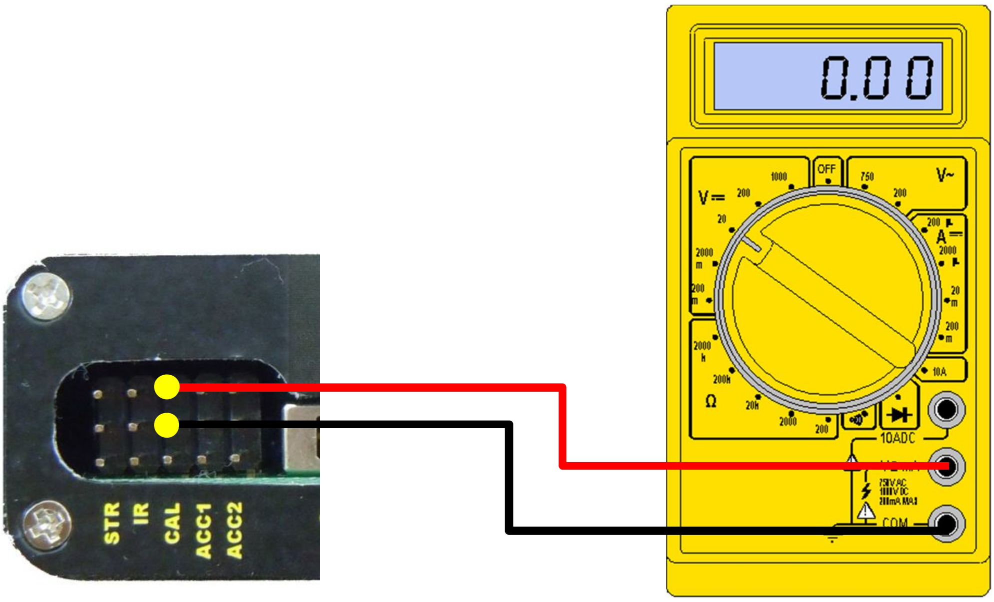


CALIBRATING THE ACCELEROMTER

If you have the latest version of Vortex, ignore this section. The latest version of the hardware is self-calibrating. However if you have the older version, calibration can be performed as follows.

To calibrate Vortex for the accelerometer location, follow the steps below:

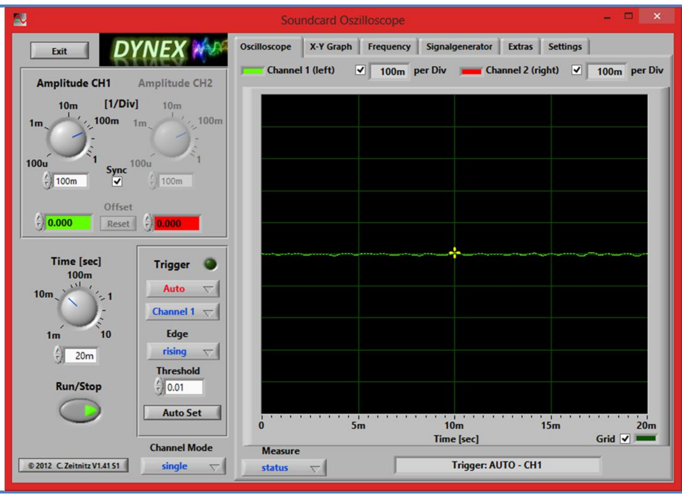
1. Connect accelerometer to Vortex ACC1 port. Install accelerometer on test article.
2. Power on Vortex. Do <u>not</u> spin rotor.
3. Attach a multimeter to the pins illustrated below.
4. Turn the "calibrate" dial using a flat blade screw driver until the multimeter reads zero (±10mV is fine).
5. The Vortex is now calibrated and ready for use.



BALANCING SOFTWARE

Introduction

DynexHobby provides analysis tools to determine the balance of rotors. There are two tools available listed below. These can be downloaded from www.dynexhobby.com.

<table>
<tr><th>Name</th><th>Image</th><th>Application</th></tr>
<tr><td>Dynex Analysis</td><td>
</td><td>Used for all balance methods. This application runs under Microsoft Windows. Note that .NET 4 must be installed for this application to function.</td></tr>
<tr><td>Scope Tool</td><td>
</td><td>The scope tool can be used as an alternative to the Dynex Analysis package. It has a few additional features such as signal generation and vibration recording.</td></tr>
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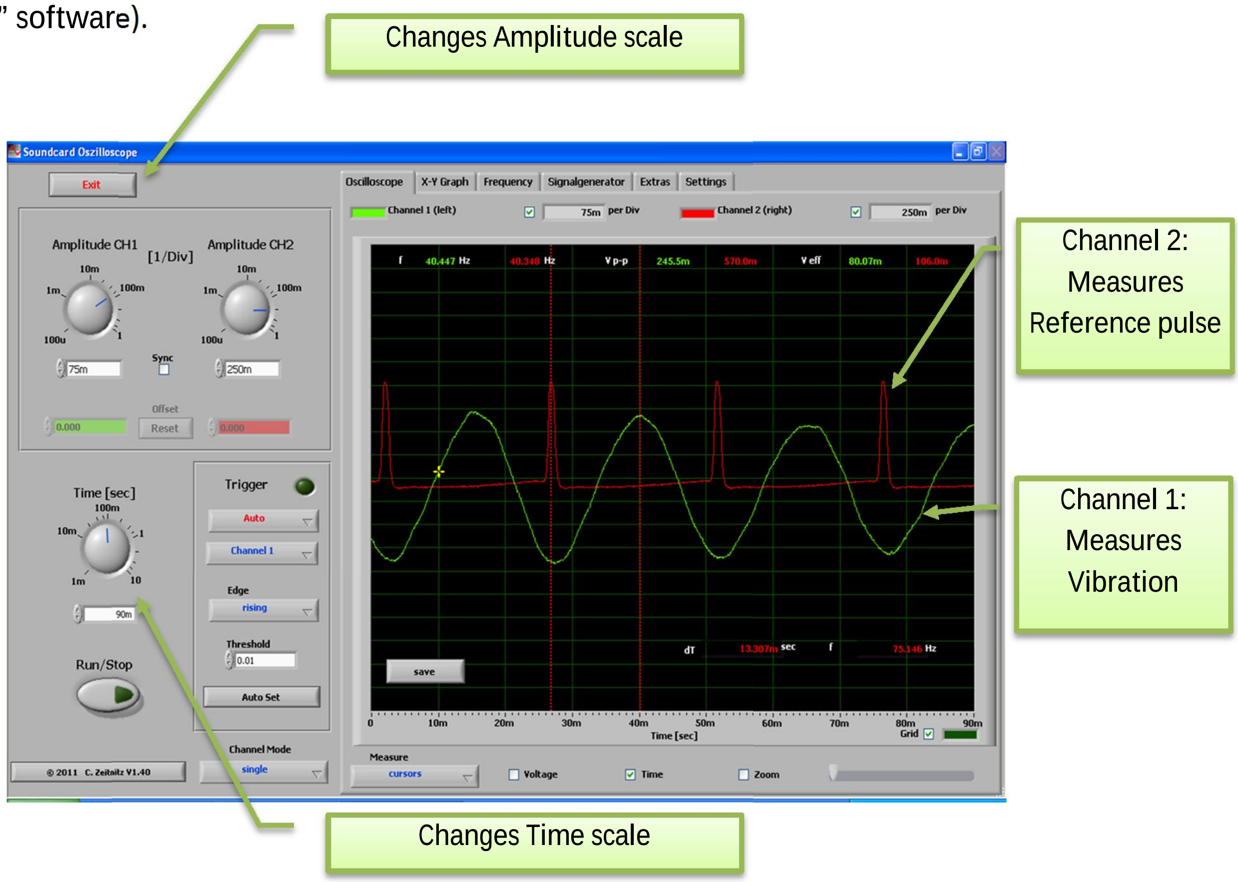
Features of vibration measuring software

The following image illustrates the main features of the vibration measurement software (or "Scope" software).

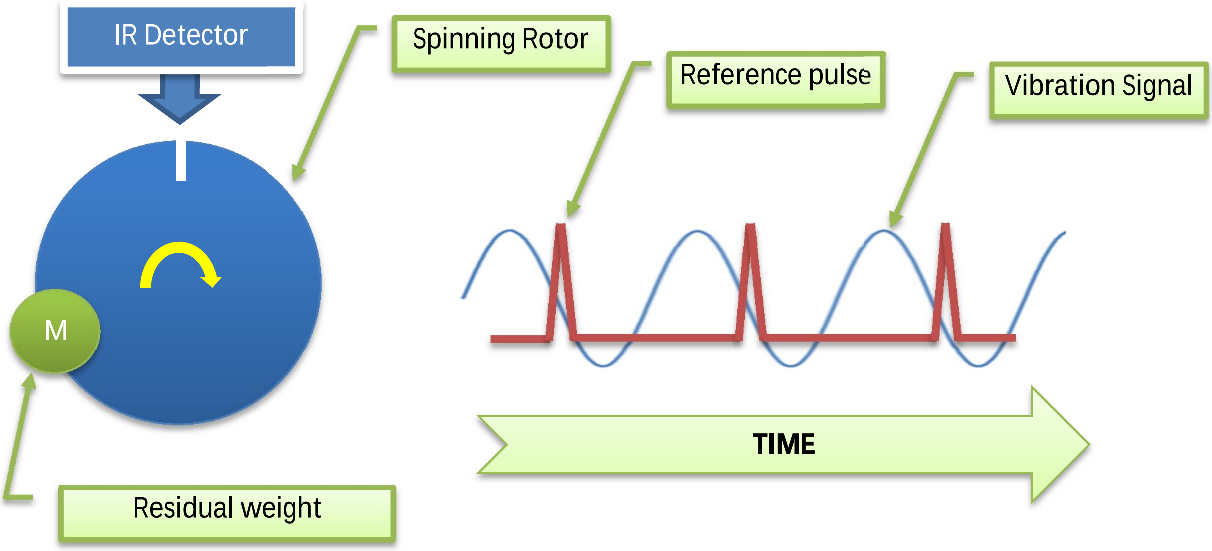


How the software measures vibration for balancing

The following image illustrates how the software measures vibration amplitude and phase. Vibration amplitude is typically measured by channel 1 in the oscilloscope software. An imbalance appears as a **sinusoidal** waveform.

A marker is applied to the rotor such as a white line or a reflective strip. As the marker passes the IR Sensor, a pulse is registered. This pulse refers to a **zero** degree reference position on the rotor. The pulse is typically measured by channel 2 in the oscilloscope software. The time difference between the reference pulse and the sinusoidal waveform is referred to as the **phase shift**. Phase shift usually measured in **degrees** of rotation.

Note: Sometimes a perfect waveform cannot be achieved due to external noise from bearings or loose mechanical connections. Vortex can filter such noise by switching on the filter and adjusting the "filter" dial on the front panel until a suitable waveform is obtained. Once the filter has been set, do not change for the remainder of the balancing operation. Additional filtering can be achieved using the DynexHobby software.


IR Detector
Spinning Rotor
Reference pulse
Vibration Signal
M
TIME
Residual weight

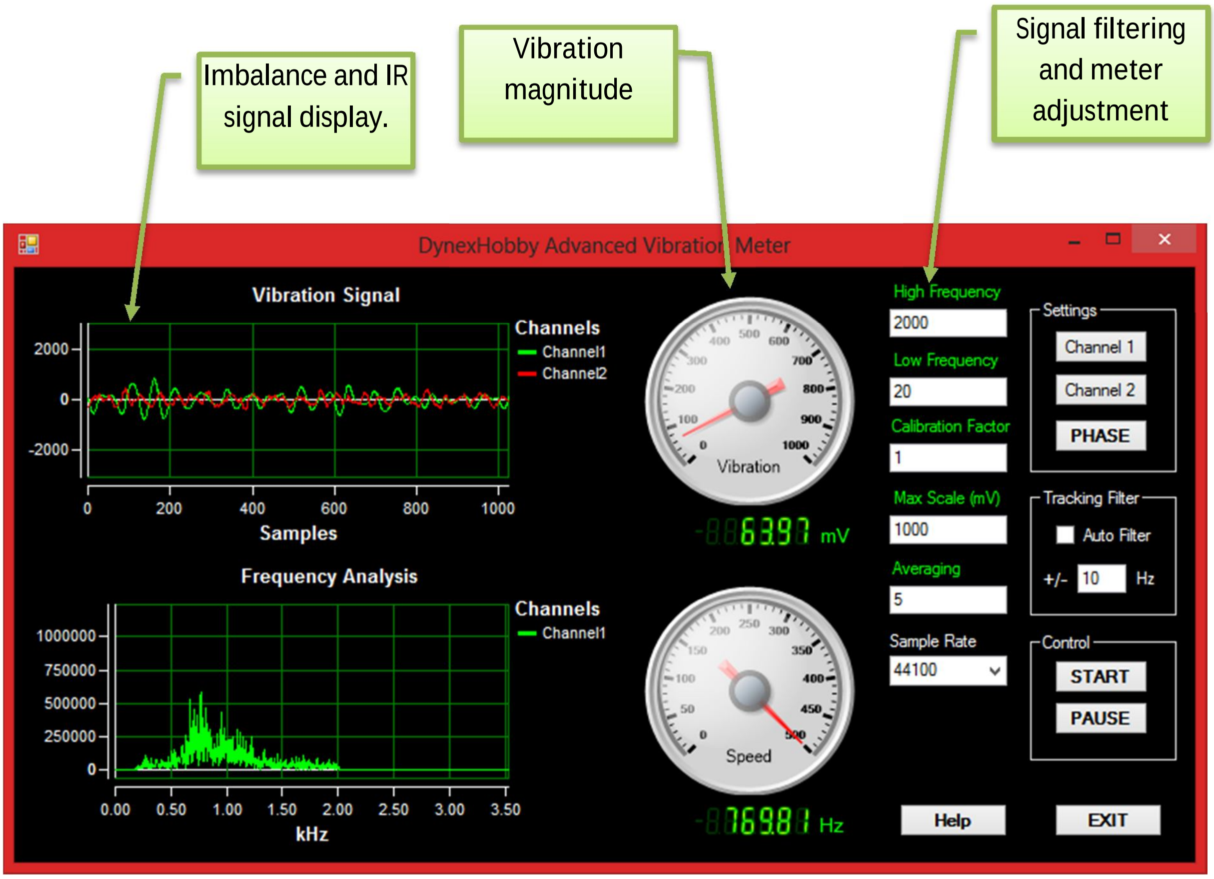
DynexHobby Vibration Meter Applications

Dynex Hobby provides easy to use vibration meters. The meter was designed to interface directly with the Vortex unit. For simple balancing operations, the vibration meter can substitute for the “scope” software.

There are two vibration meters available, an advanced meter and a basic meter which includes phase measurement.

DynexHobby Advanced Vibration Meter Application

The advanced meter has most features that you would see in an oscilloscope. The meter allows the user to visualize the imbalance and IR signals in real time as well as display the frequencies of the imbalance. The advanced meter is a powerful tool for analyzing vibrations. It provides advanced signal filtering to isolate the imbalance signal from noise.



"**High Frequency**" cuts frequencies for Channel 1 <u>above</u> the value entered into the text box.

"**Low Frequency**" cuts frequencies for Channel 1 <u>below</u> the value entered into the text box.

"**Calibration Factor**" scales the magnitude. It also allows the operator to calibrate the vibration readings with an external source.

"**Max Scale**" allows the operator to adjust the scale on the vibration meter.

"**Averaging**" averages the measurements taken across the sample size. The larger the number the more averaging is performed. A larger average helps stabilize the meter dial.

"**Sample Rate**" defines the sample rate of the signal. Units are samples/second.

"**Settings Box**" allows the operator to select the source of the audio device. The audio device measures the vibration level from the Vortex.

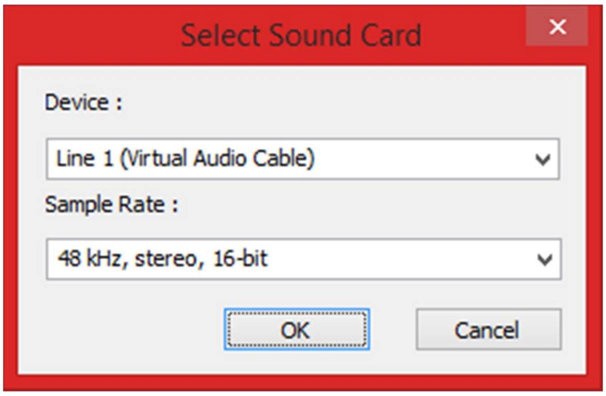
"**Tracking Filter**" is an advanced feature that automatically filters for the imbalance signal by tracking the RPM. It removes other sources of noise and displays the imbalance signal.

"**Start**" starts measuring and displaying the vibration signal.

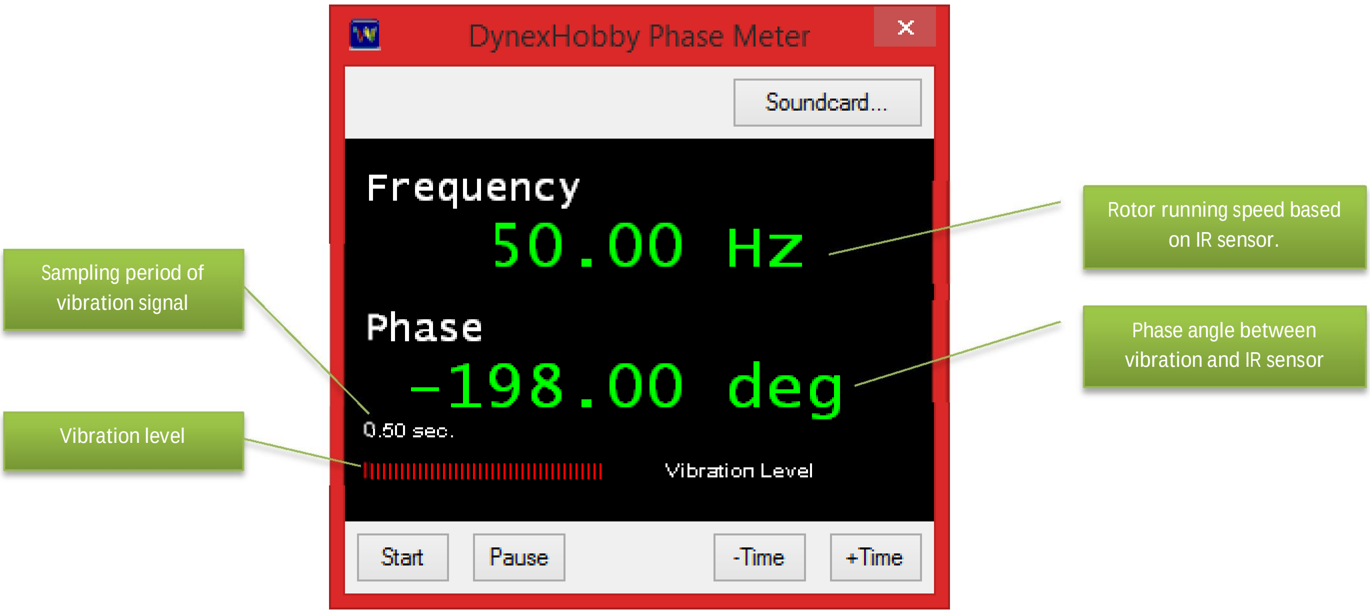
"**Pause**" stops measuring and displaying the vibration signal.

DynexHobby Basic Phase Meter Application

The phase meter automatically measures the phase angle between two signals. To enable the basic phase meter, click on "Basic Phase Meter" in the main menu. A new window will appear. Select the sound card or windows audio device and the sample rate. The software will automatically detect the devices available on your PC.



The vibration meter will appear and proceed to record vibration data. No filtering is available with the basic meter. The follow describes the functions of the meter;



"**Sound card**" button allows the operator to set the sampling rate of the vibration signal.

"**Start**" and "**Stop**" buttons will start recording data and also pause the on screen readings.

"**-Time**" and "**+Time**" buttons will decrease on increase the sampling period of the vibration signal.

"**Vibration**" level bar graph will indicate if the vibration level exceeds the operational limits of the Vortex unit.

BASIC THEORY OF BALANCING

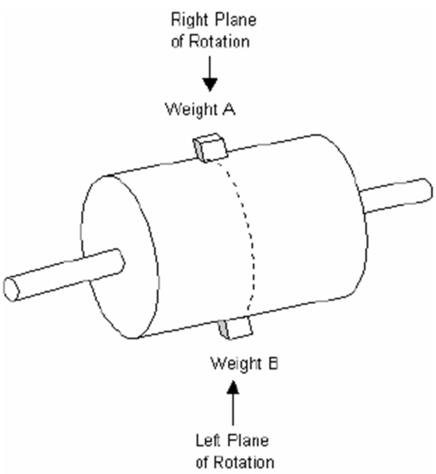
Introduction

Unbalanced rotors have relatively high force effects on bearings. High levels of unbalance can cause vibration, deformation, power degradation, friction and can degrade service life. In the case of a rotating shaft, the unbalance causes periodical forces to the suspension system which corresponds to the rotational speed. In other words it is synchronous with rotational speed (first order). In order to balance the rotor the correct running speed should be selected in the balancing instrument. The test speed is usually much lower than the operational speed for safety reasons. The correct running speed reduces the disturbance caused by the noise, harmonics, bearings and blade frequencies.

The unbalance is radial in their line of action and it is a vector quantity. A vector has both magnitude and direction. The direction can be characterized by the phase between the unbalance vector (from the center of the shaft) and a vector to the reference point at the shaft (from the center of the shaft).

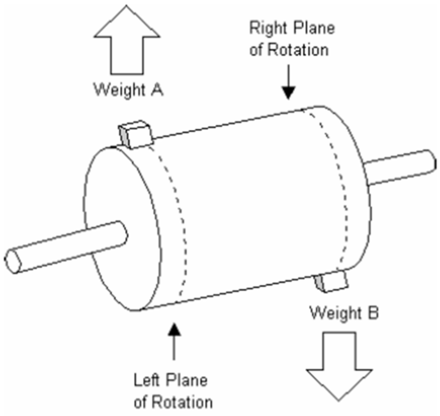
Static Unbalance

The general dynamic unbalance consists of the static (**single plane)** unbalance. This is when the mass center line is **parallel** and not coincidental with the rotational axis. This kind of balance exists in disk shape structures. It can be eliminated by a compensating weight. This method is appropriate for balancing ducted fan units, wheels or any disc shaped rotors.



Coupled Unbalance

The other type of unbalance is when a pair of weights are at two ends of the shaft but on opposite sides to each other (180°). The rotor is in static balance, but the centrifugal forces will produce a moment about the center of mass when the rotor turns. In this case, only a couple unbalance exists. The mass center line **crosses** the shaft axes at the center of gravity.

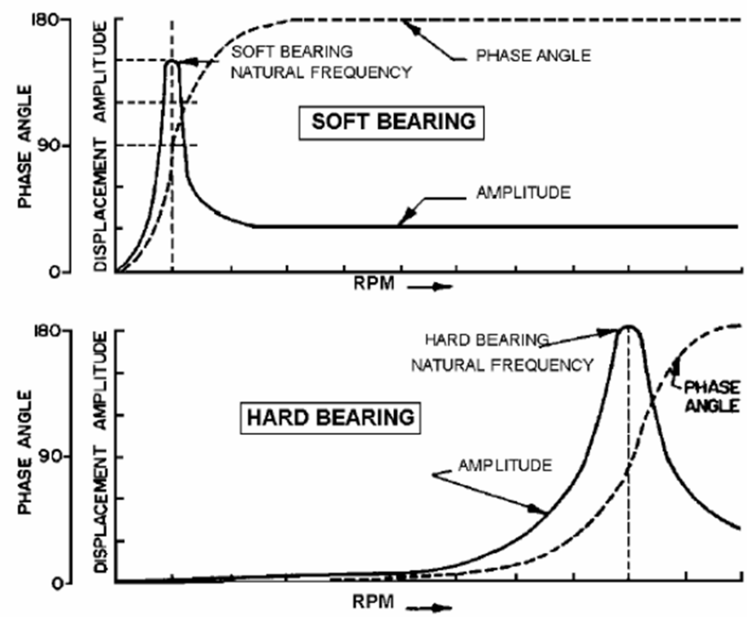


The couple unbalance can be compensated by two weights, which are positioned to counteract the couple unbalance at two planes. The ideal balancing task is to reduce the inhomogeneous mass distribution caused forces by adding or removing weights along the shaft.

Suspension System (mounting cradle)

The suspension system or the mounting cradle is crucial for balancing. The cradle allows the rotor system to oscillate back and forth near its natural state. The oscillation is important for Vortex to sense vibration and analyze the imbalance. *Note: Mounting cradles are not supplied by Dynex Hobby. Cradles can easily be made from components supplied by your local hardware or electronics store*.

Each suspension system has a natural mode of vibration or natural frequency. If tests are conducted at the natural frequency (a specified RPM that cause's natural vibration of the system), then the balancing results will be difficult to achieve.



To avoid this, the following recommendations should be considered:

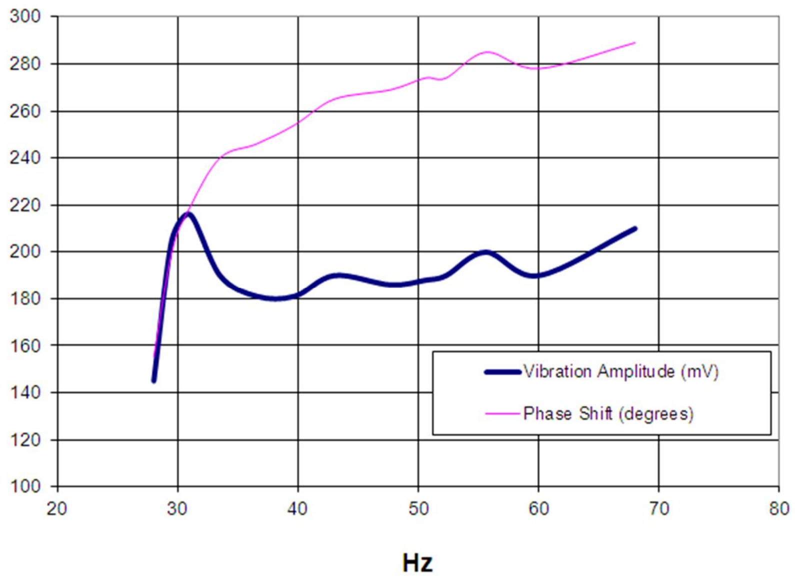
- Run balancing at speeds above or below the natural frequency. This would be in a region where phase angle and amplitude are flat in the charts above.
- Soft suspension construction to provide a low resonance frequency.
- Allow the cradle to rock smoothly using frictionless supports. Teflon bearings or magnetic supports are ideal.
- Provide additional damping to reduce overshoot of the cradle. Foam rubber works well.
- Mechanically isolate the suspension system from the bench. This can be achieved by using a rubber mat.

Determining the Suspension System Natural Frequency

The following is a simple method for identifying the suspension system natural frequency.

- ✓ Mount rotor in cradle.
- ✓ Run motor incrementally from the lowest possible RPM to the highest **safest** speed. Please ensure safety when operating the rotor and follow manufacturer's instructions. Protective gear is recommended.
- ✓ Plot the vibration amplitude and phase angle with incremental RPM.
- ✓ The natural frequency is identified by the peak in the vibration amplitude.

A sample of the Vortex suspension system is shown below. The ideal running speed would be above 40Hz. A running speed of 60Hz would provide better results.



Method of Balancing

The Vortex system uses a traditional approach used in industry to balancing. The following outlines the process;

1. Run the rotor at constant RPM. **Note that the rotor speed should be kept the same during all tests**.
2. Determine the original unbalance of the rotor. This can be measured as a voltage, acceleration, velocity or displacement. Vortex uses voltage.
3. Apply a trial weight and the unbalance is recorded again. This step is important as it creates a shift in the unbalance location. Dynamic balancers use this information to learn about the behavior of the system in order to correct for it.
4. Determine the correction weight required and position.
5. After the correction weight is applied, the unbalance is again measured. The unbalance remaining after balancing is called residual unbalance.
6. If the residual unbalanced is unacceptable then the process is repeated.

The following methods are used by Vortex for balancing;

1. Strobe Method
2. Single Plane Balance
3. 4 Point Balance Method
4. 2 Blade Propeller Balance

STROBE METHOD

When to use this method:

- A simple balance without relying on a PC.

Limitations

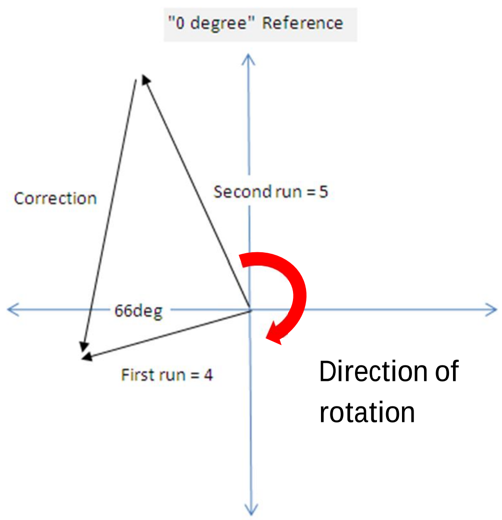
- Accuracy is adequate but limited by user ability.
- Sensitive to mounting system setup.

STEP 1 - Setup

- ✓ Setup device in mounting frame
- ✓ Ensure adequate spring and dampening is set.
- ✓ Ensure accelerometer is calibrated for mounting location.

STEP 2 – Original Vibration (No weights) – First Run

- ✓ Run device at test speed. Example **40Hz**.
- ✓ Turn Vortex on and press **mode button** to enter into strobe mode. The Vortex **strobe light** will flash twice. This indicates that Vortex has entered into the **learning circuit mode**. The learning circuit records the vibration level during the test for 10 seconds. Once this is completed, the **green** light will appear on the Vortex panel.
- ✓ Adjust the **trigger dial** until it produces a single solid line on the rotor.
- ✓ Record the vibration **trigger level**. Example trigger level for the first run was **4**.
- ✓ Record the **phase angle position** (the angle the strobe line appears relative to the zero reference position).
- ✓ Draw the phase angle and trigger level on a balance sheet for the first run. See figure below. Balance sheet is available in the appendix.



STEP 3 – Trial unbalance – Second Run

- ✓ Apply a test weight at the zero reference position. Example **0.3 gram**.
- ✓ Run device at test speed. Example **40Hz**.
- ✓ Adjust the **trigger dial** that produces a solid single line on the rotor.
- ✓ Record the vibration **trigger level**. Example trigger level for the second run was set to **5**.
- ✓ Record the **phase angle position** (the angle the strobe line appears to the zero reference position).
- ✓ Draw the phase angle and trigger level on a balance sheet for the second run.

STEP 4 – Calculate correction weight

- ✓ Draw a vector (line) from the second run to the first run.
- ✓ Measure the included angle between the **correction** vector and the **first run**. Example **66 degrees**.
- ✓ Calculate the required correction weight as follows;

  Correction weight = First run trigger level / Correction vector length x Trial weight

  = 4 / 5 x 0.3 gram
  = 0.24 gram (approx.)

- ✓ The correction weight is applied in the opposite direction to the second run vector shift. For example, the second run vector shifted clockwise relative to the first run. The correction weight of **0.24 gram** is then applied **66** degrees **counter clockwise** from **the zero degree** reference position.

STEP 5 – Check balance

- ✓ Run device at test speed. Example **40Hz**.
- ✓ Adjust the **trigger dial** that produces a solid single line on the rotor.
- ✓ Record the vibration **trigger level**. Example trigger level was set to **2**. Since the trigger level is less than the original 4 then an adequate balance has been achieved. *Note: It may not be possible to achieve a trigger level much less than this due to the sensitivity of the circuit*.

SINGLE PLANE DYNAMIC BALANCE

When to use this method:

- Generally can be used on most occasions
- When you want precise balancing with minimal residual unbalance
- Strobe Method doesn't provide adequate results.
- Recommended method as vibration phase, amplitude and residual imbalance can be calculated.

Limitations

- Excessive vibration beyond Vortex capabilities
- Extreme levels of coupled unbalance

Note this example uses the Scope software to illustrate vibration measurement. The Dynex advanced vibration meter can be used in the same way.

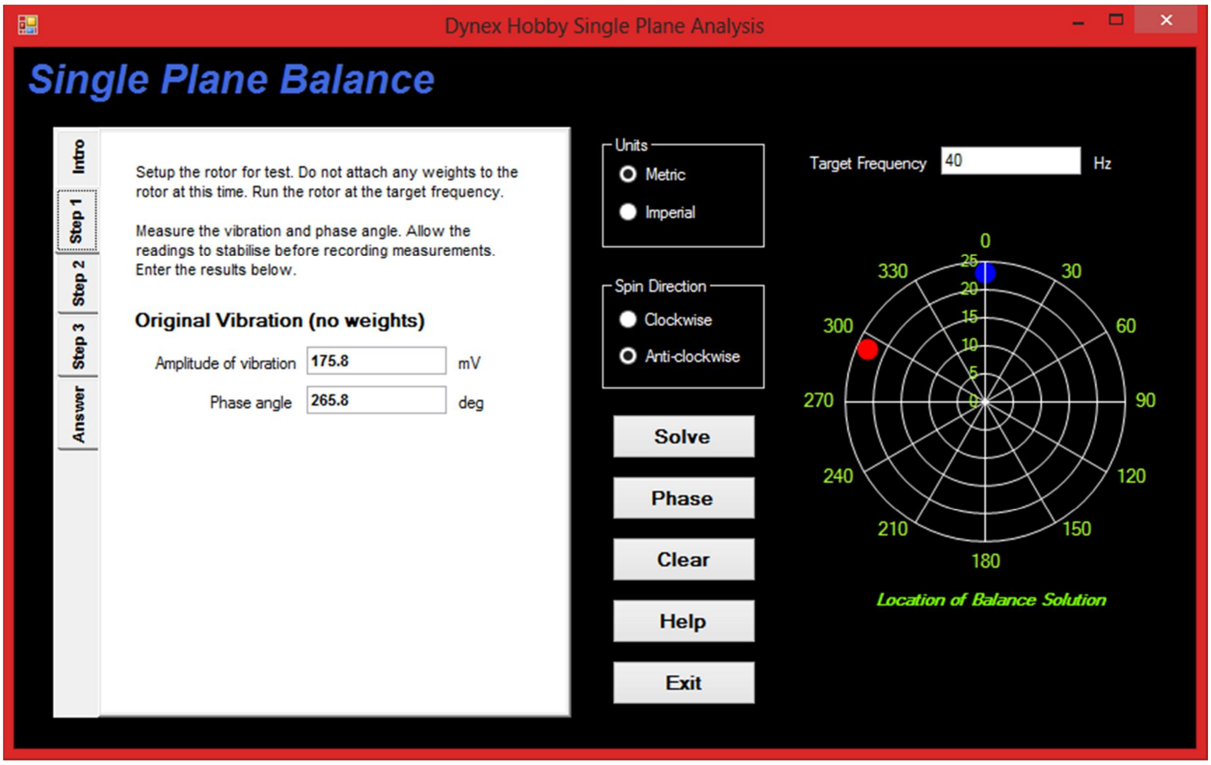
Setup

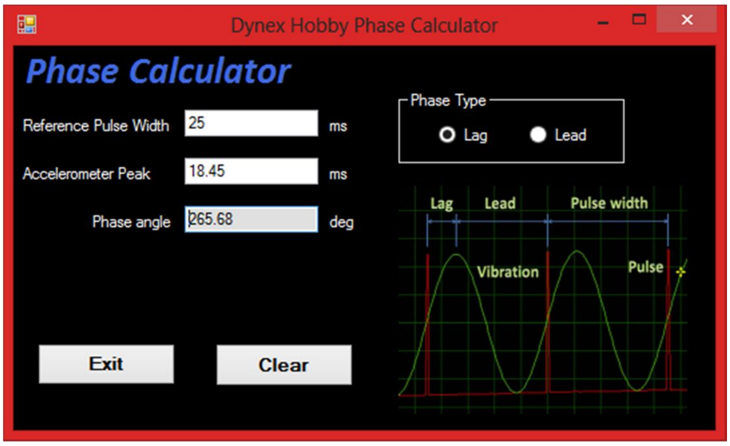
- ✓ Setup device in mounting frame
- ✓ Ensure adequate spring and dampening is set.
- ✓ Ensure accelerometer is calibrated for mounting location.
- ✓ Connect Vortex to PC.
- ✓ Determine running speed that produces a nice sine wave on the oscilloscope display.

STEP 1 – Original Vibration (no weights)

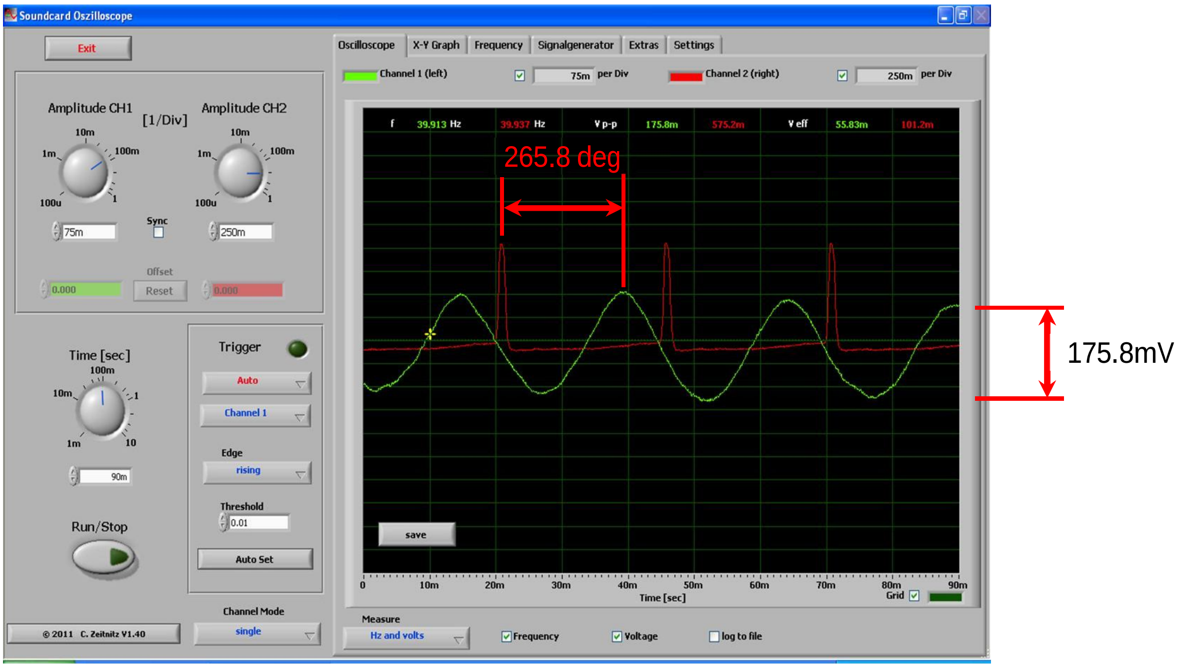
- ✓ Run device at test speed. Example **40Hz**.
- ✓ Record vibration amplitude. Example **175.8mV** Peak to Peak. Enter this value in **Vortex Analysis Tool.**
- ✓ **Note:** Do not change gain setting between test runs.

- ✓ Measure phase shift. Example **265.8 degrees** from start of reference pulse to first peak of sine wave. Enter this value in **Vortex Analysis Tool.**



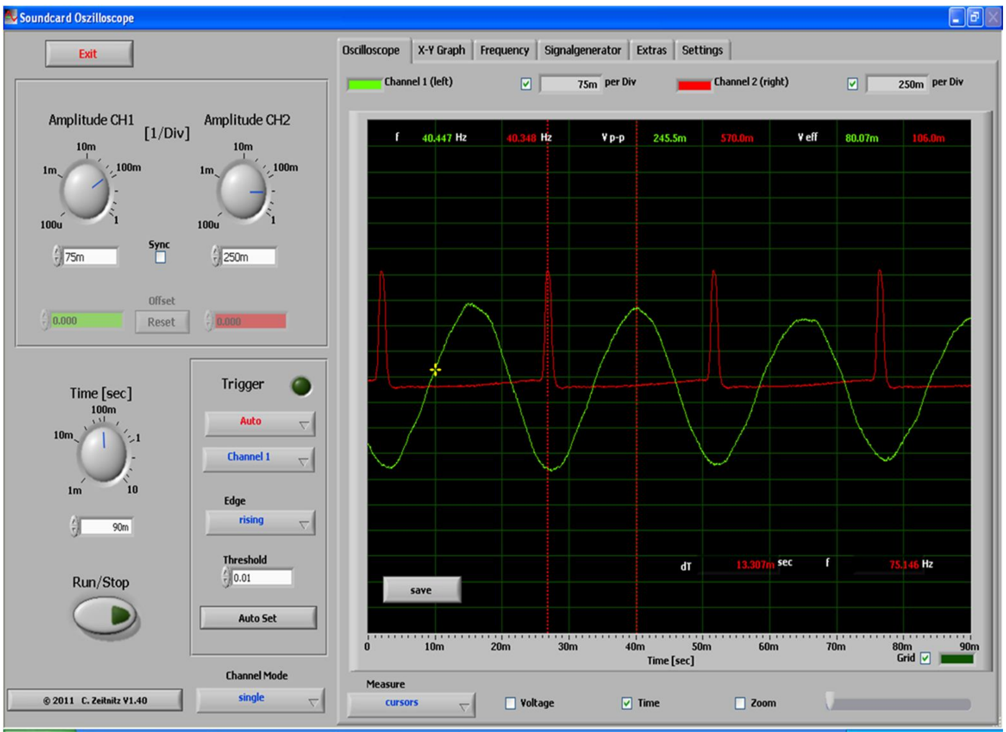


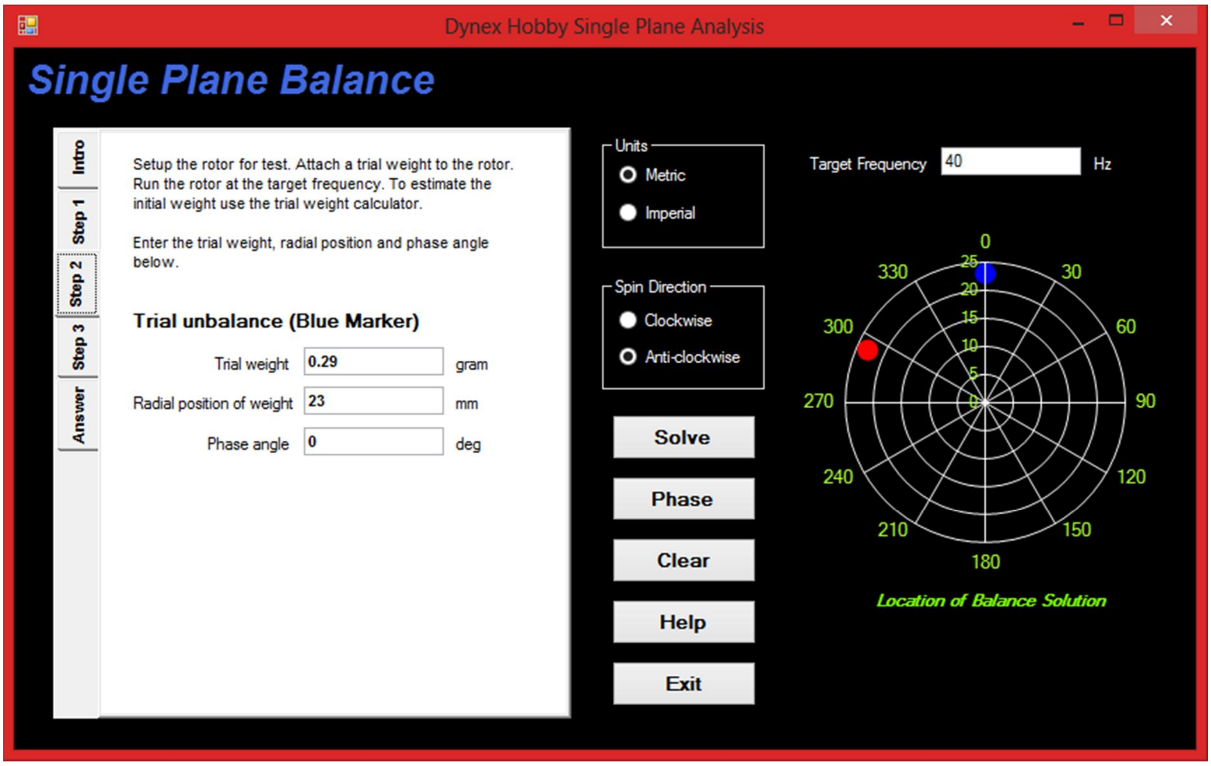
TIP A calculator has been provided in the Vortex Analysis Tool. Simply enter the time between the peaks of the reference pulse in the first cell. The second cell has the time between the first refence pulse and the first sine wave peak. The phase is calculated automatically between the two signals.



STEP 2 – Trial Unbalance

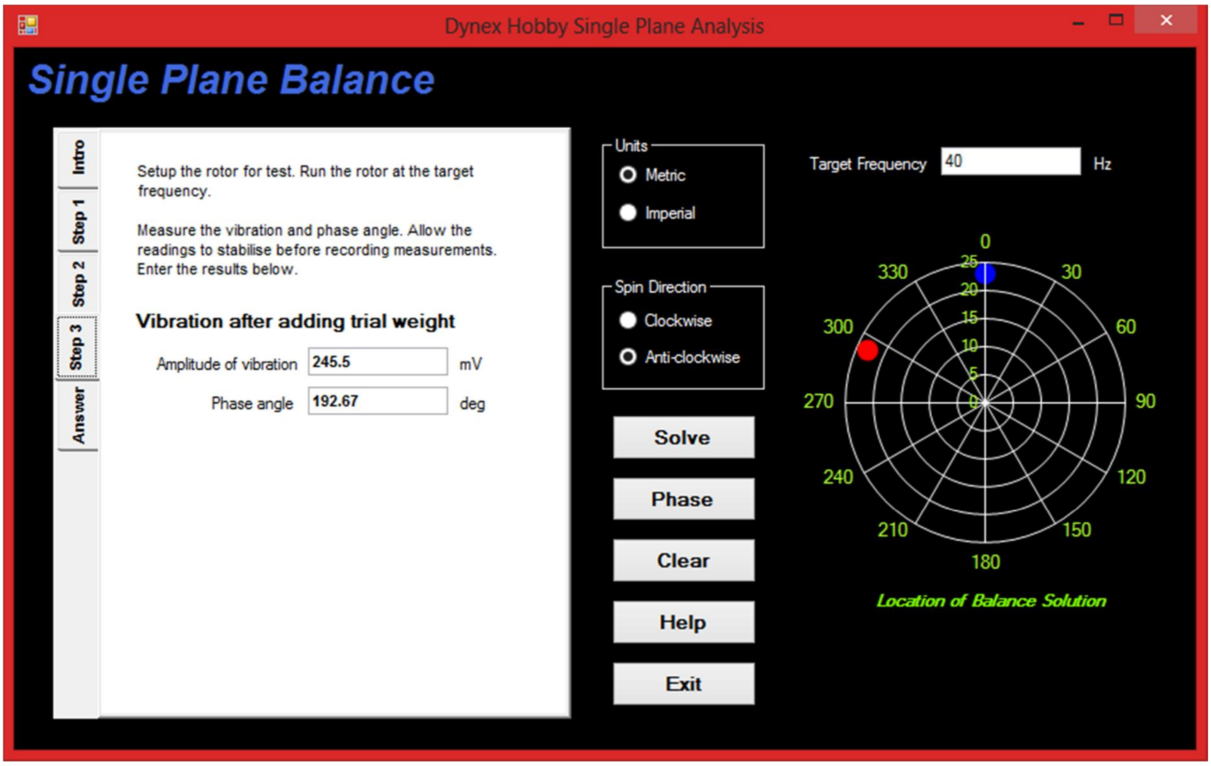
- ✓ Place a trial weight at the **zero** degree position. Example **0.29 gram** at zero degrees positioned **23mm** from axis of rotation.
- ✓ Run device at test speed. Example **40Hz.**
- ✓ Record vibration amplitude. Example **245.5mV** Peak to Peak. Enter this value in **Vortex Analysis Tool.**
- ✓ Measure phase shift. Example **192.7 degrees** from start of reference pulse to first peak of sine wave. Enter this value in **Vortex Analysis Tool.**

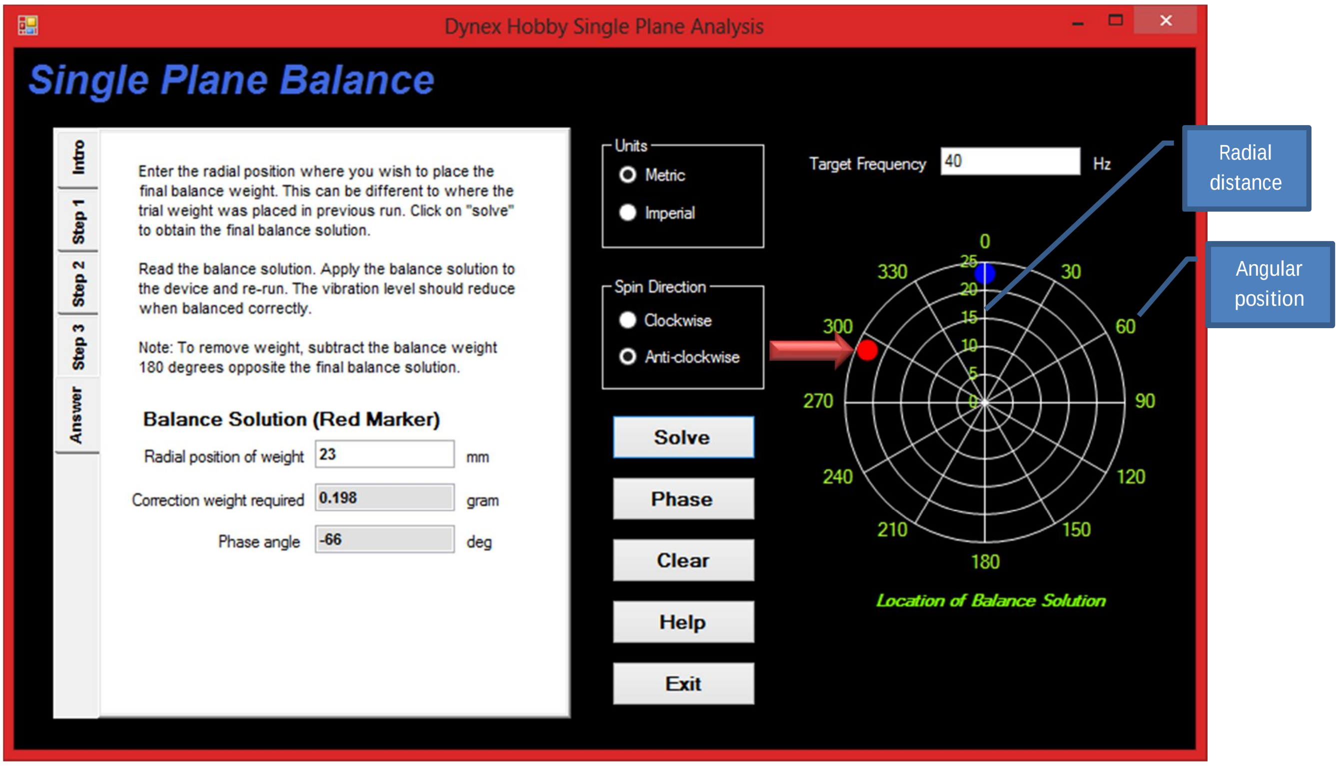




STEP 3 – Determine Required Balance weight

- ✓ Required balance weight is read direct from **Vortex Analysis Tool**.
- ✓ Apply balance weight (example **0.198 gram**) to hub at the required radial position (example **23mm**). ***Note*:** The radial position can be changed to a new distance away from the axis of rotation if desired.





Dynex Hobby Single Plane Analysis
Single Plane Balance
Intro
Step 1
Step 2
Step 3
Answer
Enter the radial position where you wish to place the final balance weight. This can be different to where the trial weight was placed in previous run. Click on "solve" to obtain the final balance solution.
Read the balance solution. Apply the balance solution to the device and re-run. The vibration level should reduce when balanced correctly.
Note: To remove weight, subtract the balance weight 180 degrees opposite the final balance solution.
Balance Solution (Red Marker)
Radial position of weight 23 mm
Correction weight required 0.198 gram
Phase angle -66 deg
Units
Metric
Imperial
Spin Direction
Clockwise
Anti-clockwise
Solve
Phase
Clear
Help
Exit
Target Frequency 40 Hz
Location of Balance Solution
Radial distance
Angular position

FOUR POINT DYNAMIC BALANCE

When to use this method:

- Generally can be used on most occasions
- When you want precise balancing with minimal residual balance
- Nonlinear conditions exist.
- Other methods do not provide adequate results.

Limitations

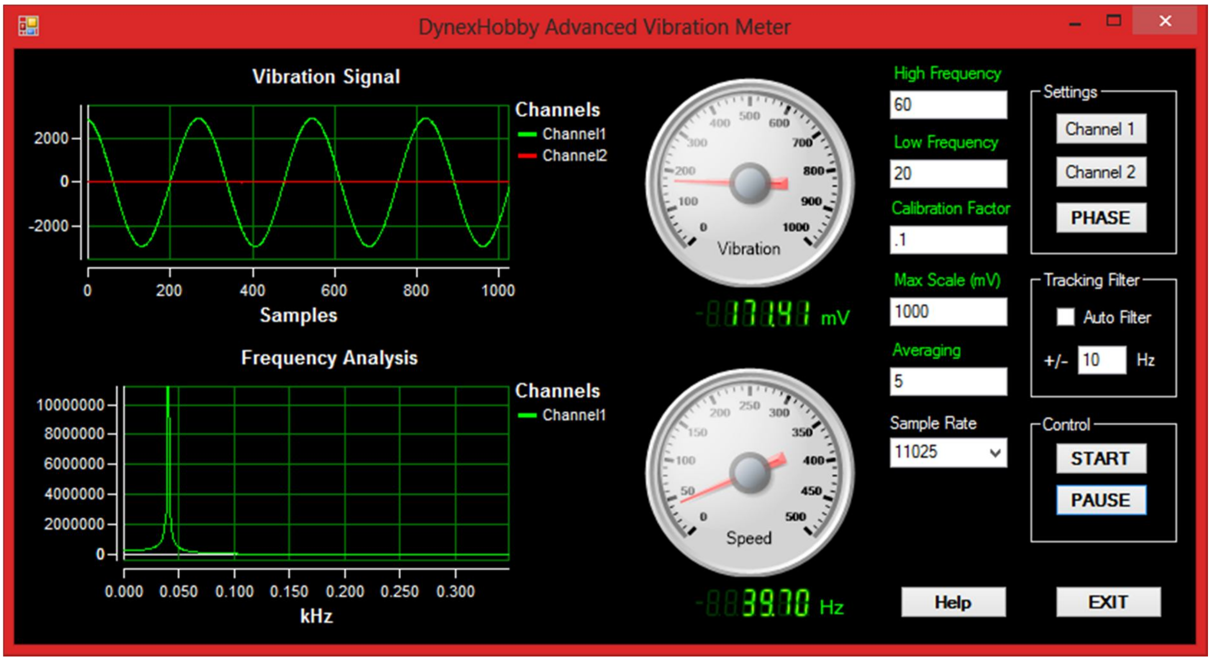
- Excessive vibration beyond Vortex limits.

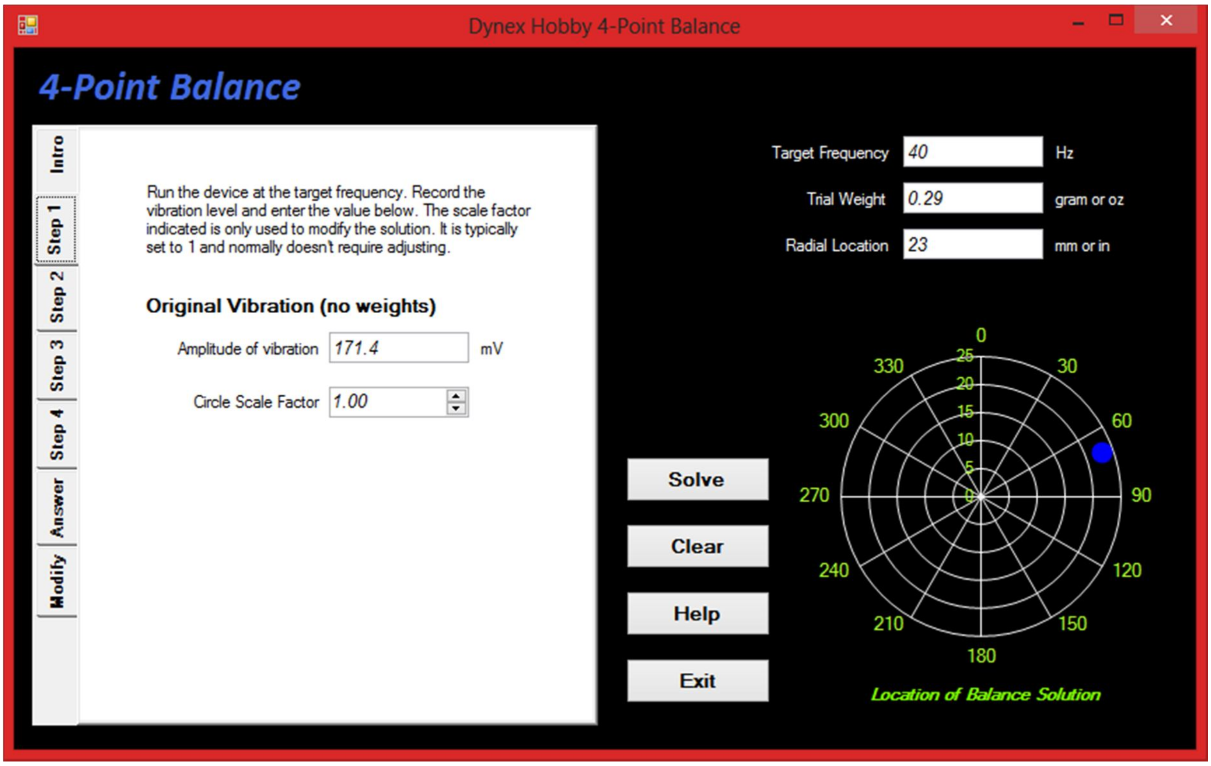
Setup

- ✓ Setup device in mounting frame
- ✓ Ensure adequate spring and dampening is set.
- ✓ Ensure accelerometer is calibrated for mounting location.
- ✓ Connect Vortex to PC.
- ✓ Determine running speed that produces a nice sine wave on the oscilloscope display.

STEP 1 – Original Vibration (No weights)

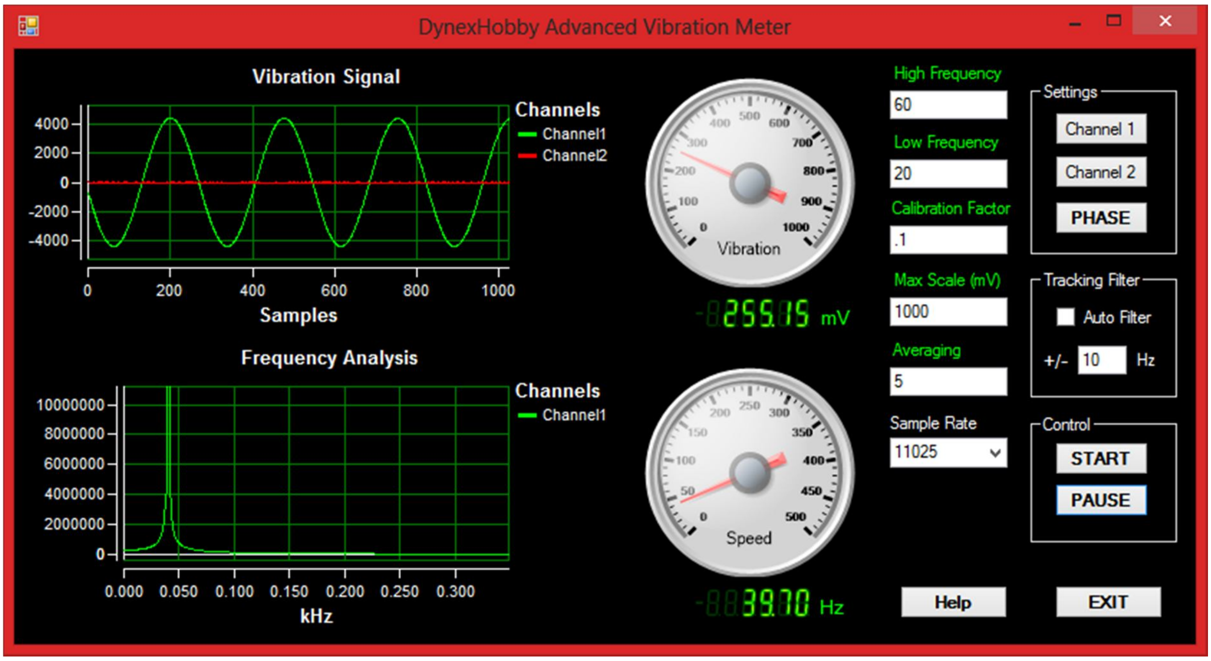
- ✓ Run device at test speed. Example **40Hz**.
- ✓ Record vibration amplitude. Example **171.4mV** Peak to Peak. Enter this value in the **4 Point Analysis Tool.**
- ✓ **Note:** Do not change gain setting between test runs.

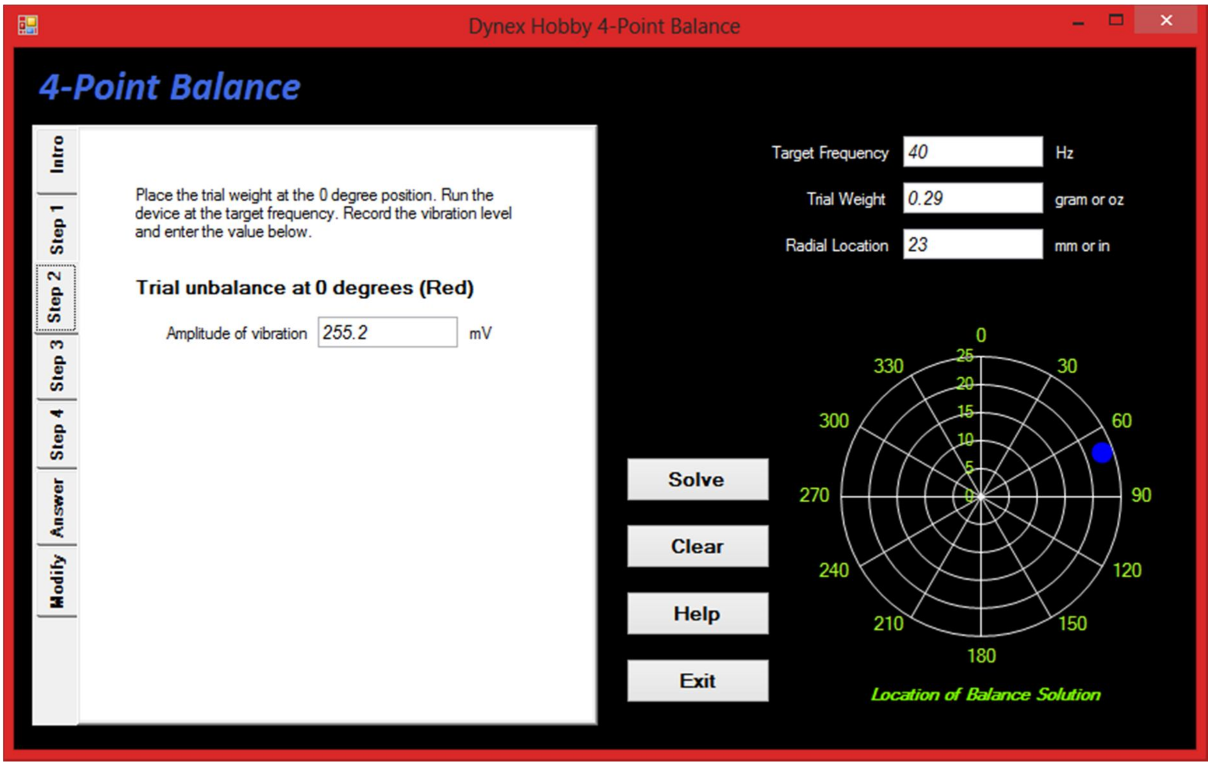




STEP 2 – Trial Unbalance 1

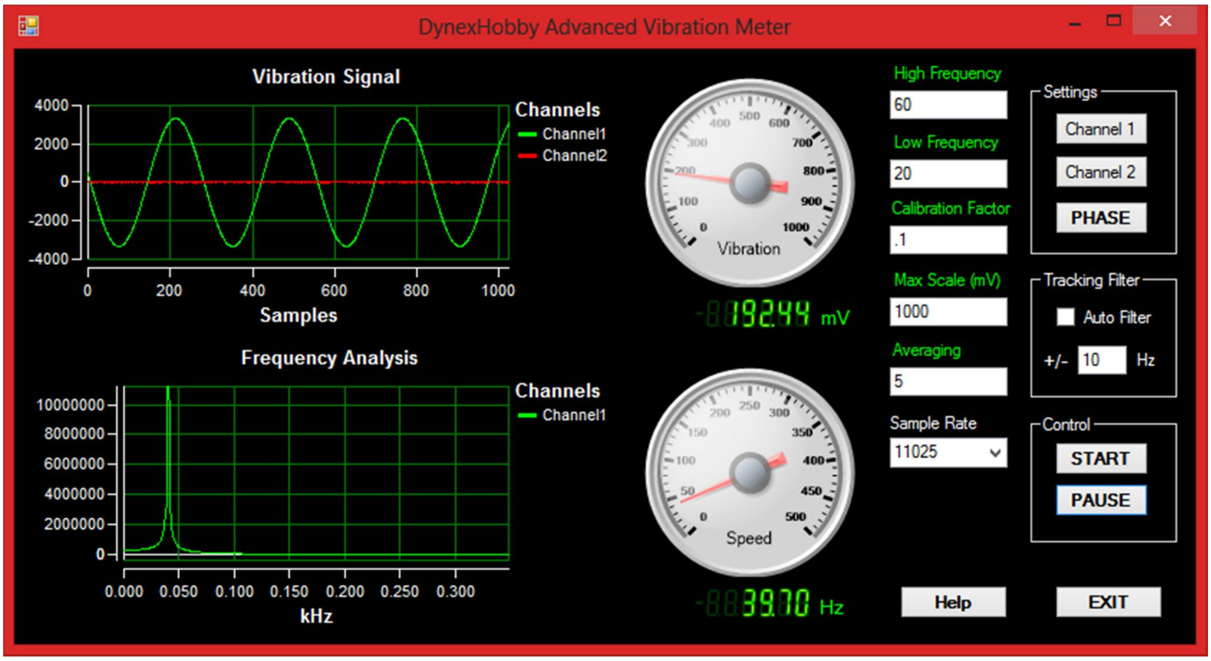
- ✓ Place a trial weight at the **zero** degree position. Example **0.29 gram** at zero degrees positioned **23mm** from axis of rotation.
- ✓ Run device at test speed. Example **40Hz**.
- ✓ Record vibration amplitude. Example **255.2mV** Peak to Peak. Enter this value in the **4 Point Analysis Tool.**

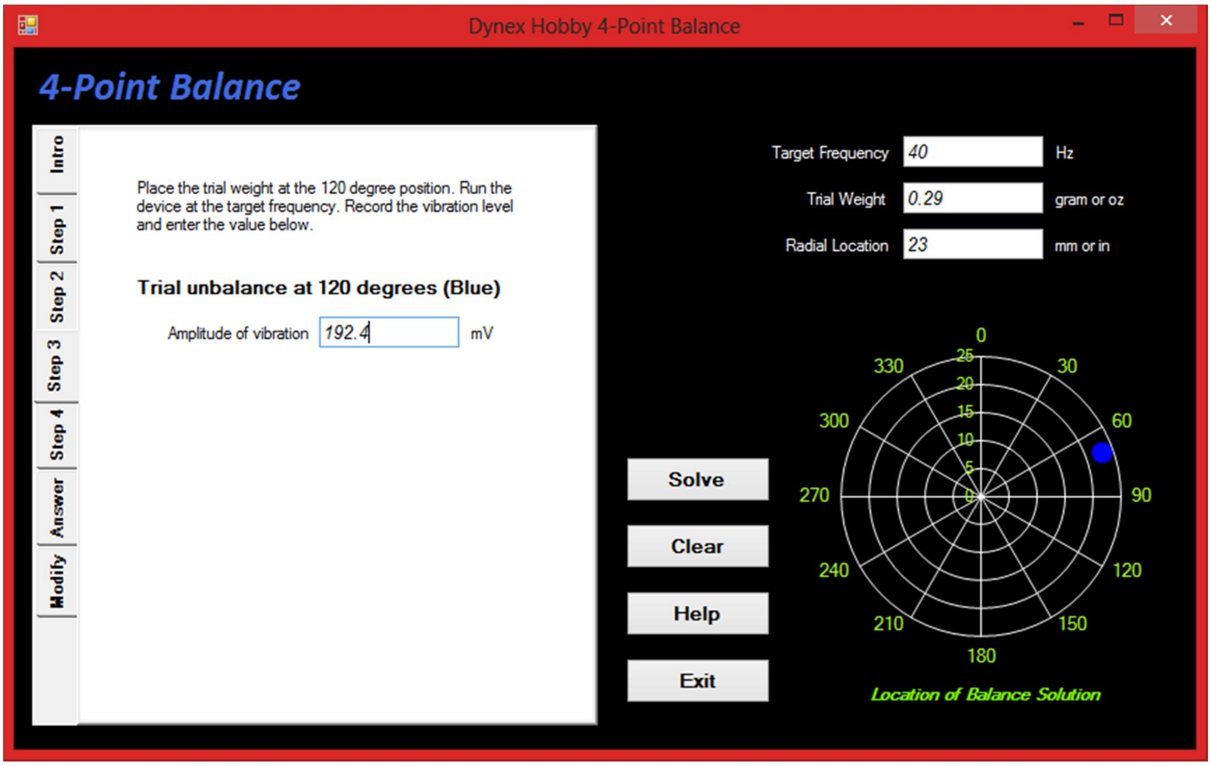




STEP 3 – Trial Unbalance 2

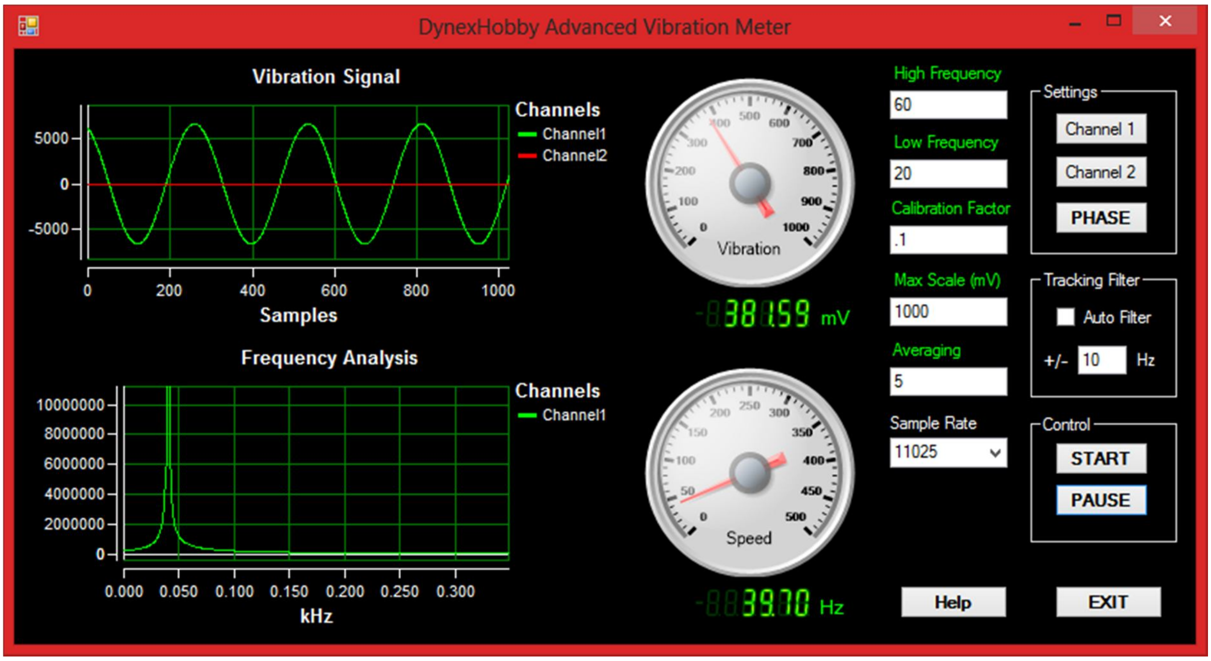
- ✓ Place a trial weight at the **120** degree position. Example **0.29 gram** at **23mm** from axis of rotation.
- ✓ Run device at test speed. Example **40Hz**.
- ✓ Record vibration amplitude. Example **192.4mV** Peak to Peak. Enter this value in the **4 Point Analysis Tool.**

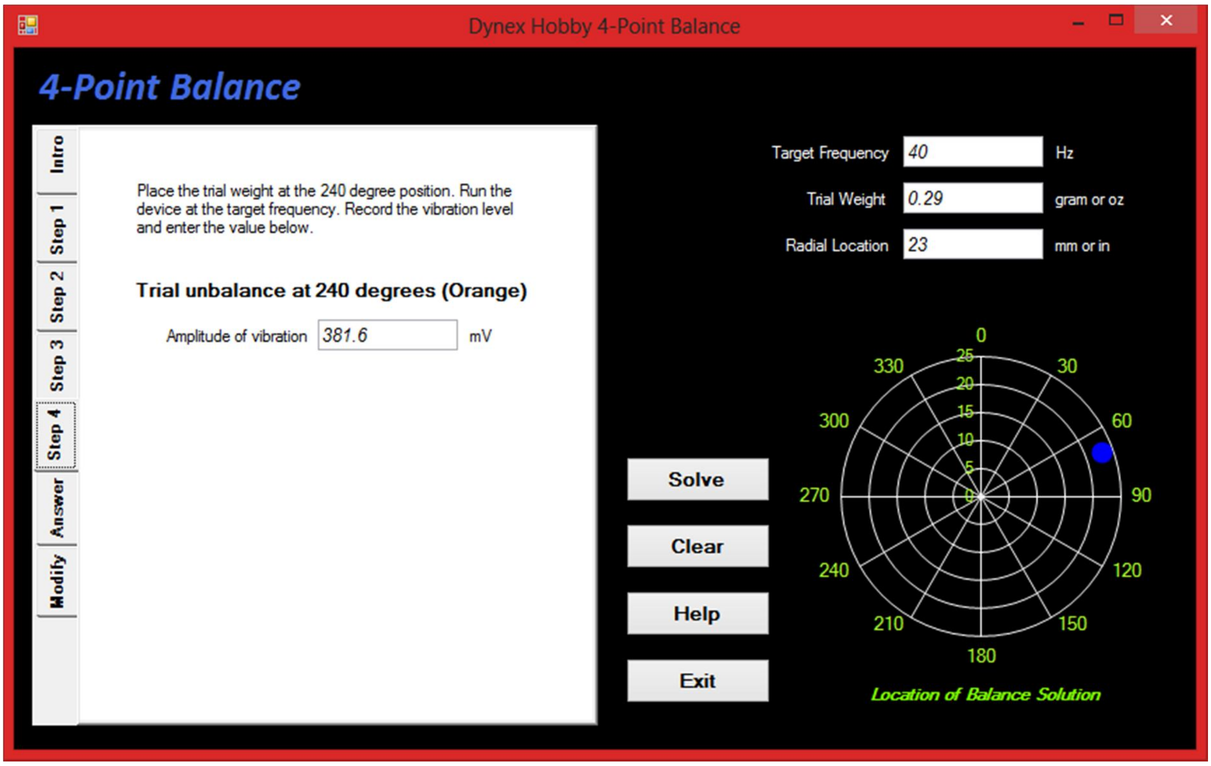




STEP 4 – Trial Unbalance 3

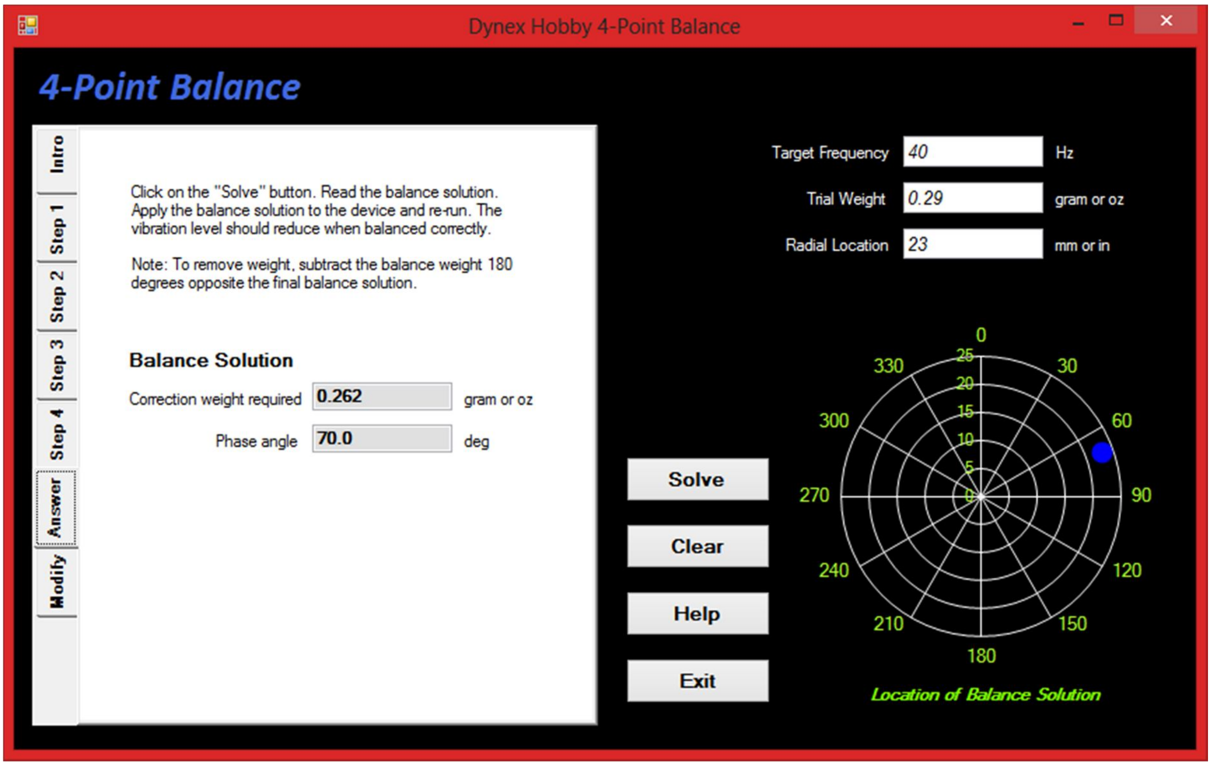
- ✓ Place a trial weight at the **240** degree position. Example **0.29 gram** at **23mm** from axis of rotation.
- ✓ Run device at test speed. Example **40Hz**.
- ✓ Record vibration amplitude. Example **381.6mV** Peak to Peak. Enter this value in the **4 Point Analysis Tool.**





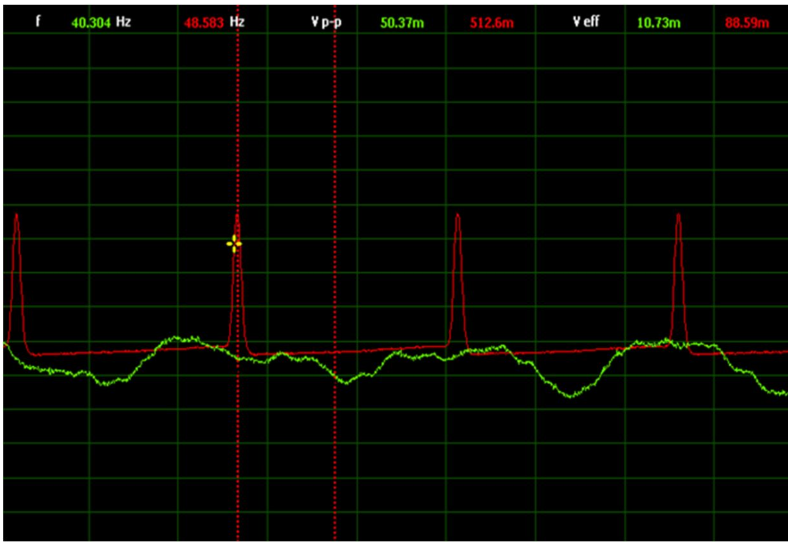
STEP 5 – Determine Required Balance weight

- ✓ Enter coordinates to position the **black marker** at the location where the **red, blue and orange** circles intersect.
- ✓ Required balance weight is read direct from the **4 Point Analysis Tool**. Example apply **0.262 gram** at the **70** degree position located **23mm** from axis of rotation.



STEP 6 – Check final balance

- ✓ Run device at test speed. Example **40Hz**.
- ✓ Record vibration amplitude. Example **50.37mV** Peak to Peak. This means the final imbalance is 340% better than the original imbalance.



2 BLADE PROPELLER BALANCE

When to use this method:

- Generally can be used on most 2 blade propellers
- When you want precise balancing with minimal residual balance
- Other methods do not provide adequate results.

Limitations

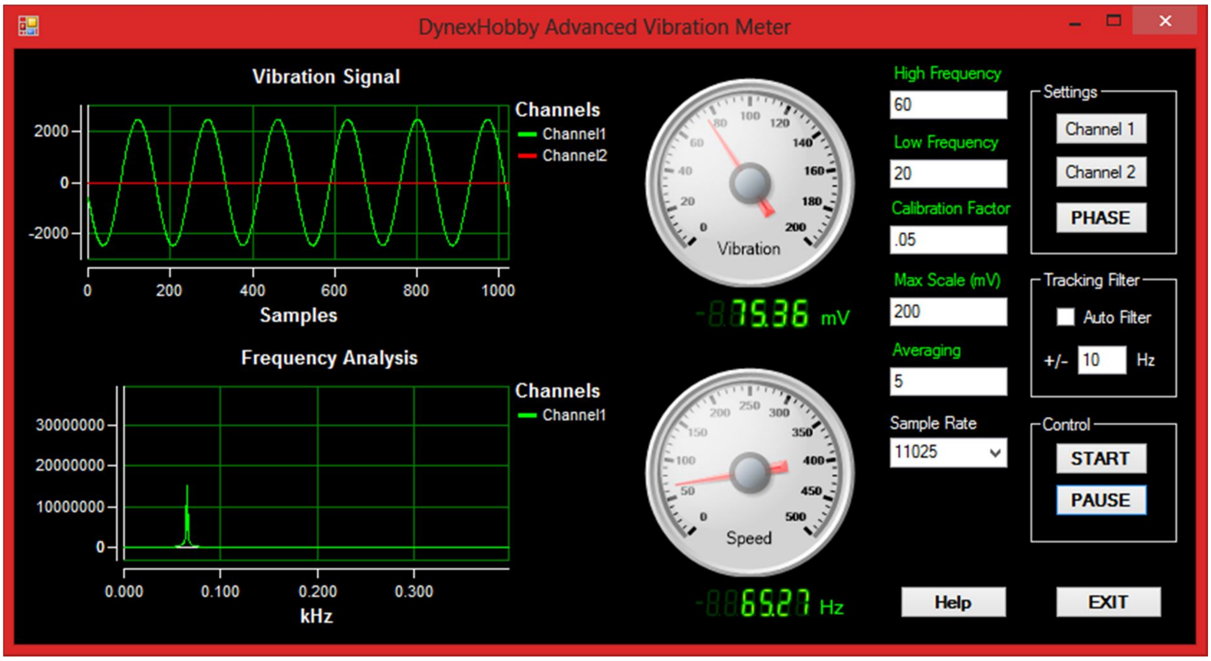
- Excessive vibration beyond Vortex limits.

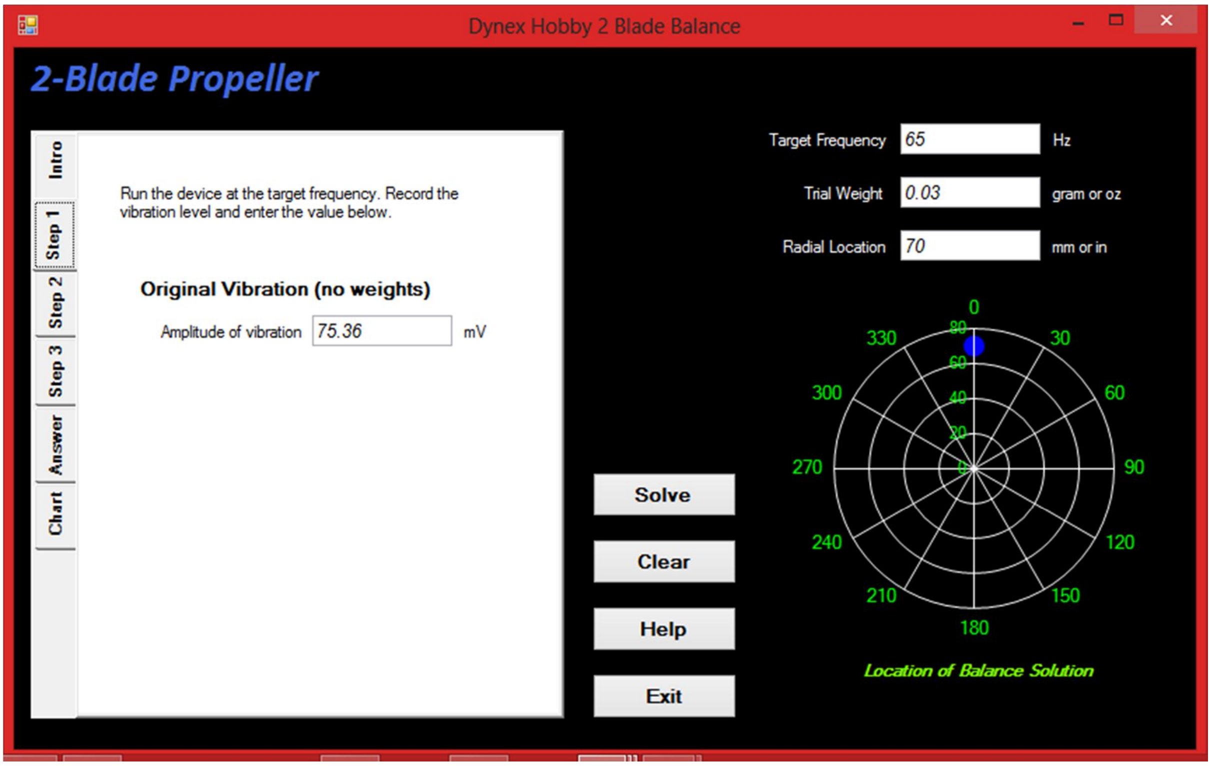
Setup

- ✓ Setup and secure propeller and motor mount to test stand.
- ✓ Attach accelerometer onto motor mount in direction of maximum vibration.
- ✓ Ensure accelerometer is calibrated for mounting location.
- ✓ Connect Vortex to PC.
- ✓ Determine running speed that produces a nice sine wave on the oscilloscope display (away from system natural frequency).

STEP 1 – Original Vibration (No weights)

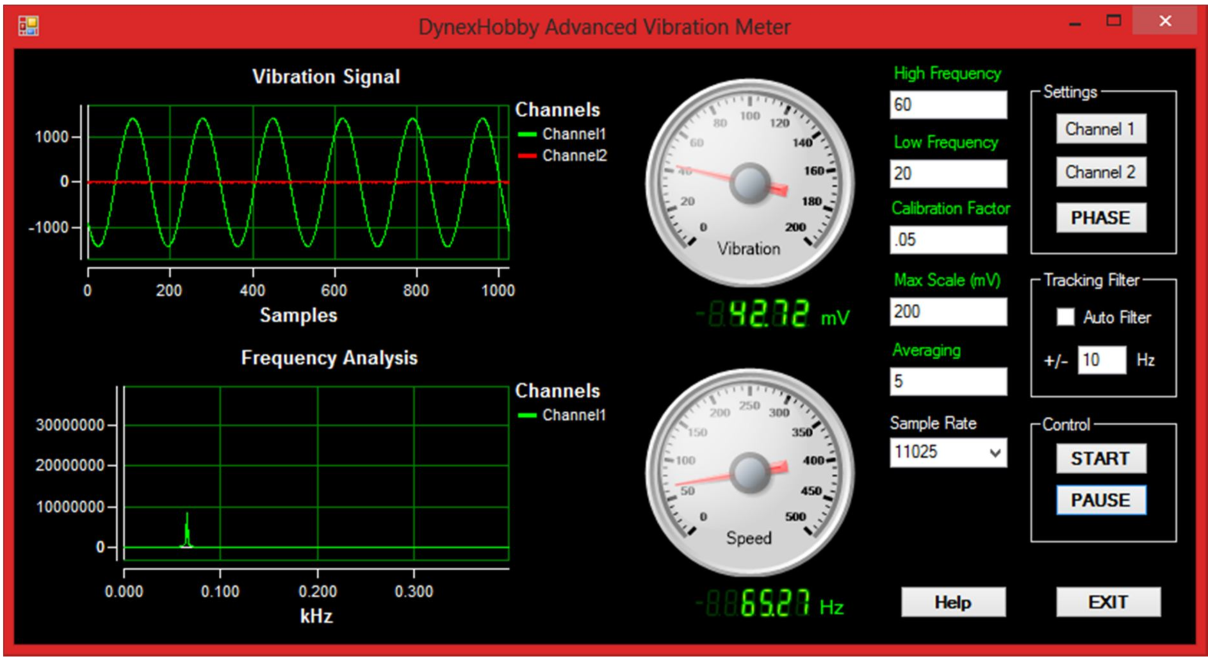
- ✓ Run device at test speed. Example **65Hz**.
- ✓ Record vibration amplitude. Example **75.36mV**. *Note the value read from the software has been scaled up by 1000 for ease of entry.*
- ✓ Enter this value in the **2 Blade Propeller Balance Tool.**
- ✓ **Note:** Do not change gain setting on the Vortex between test runs.

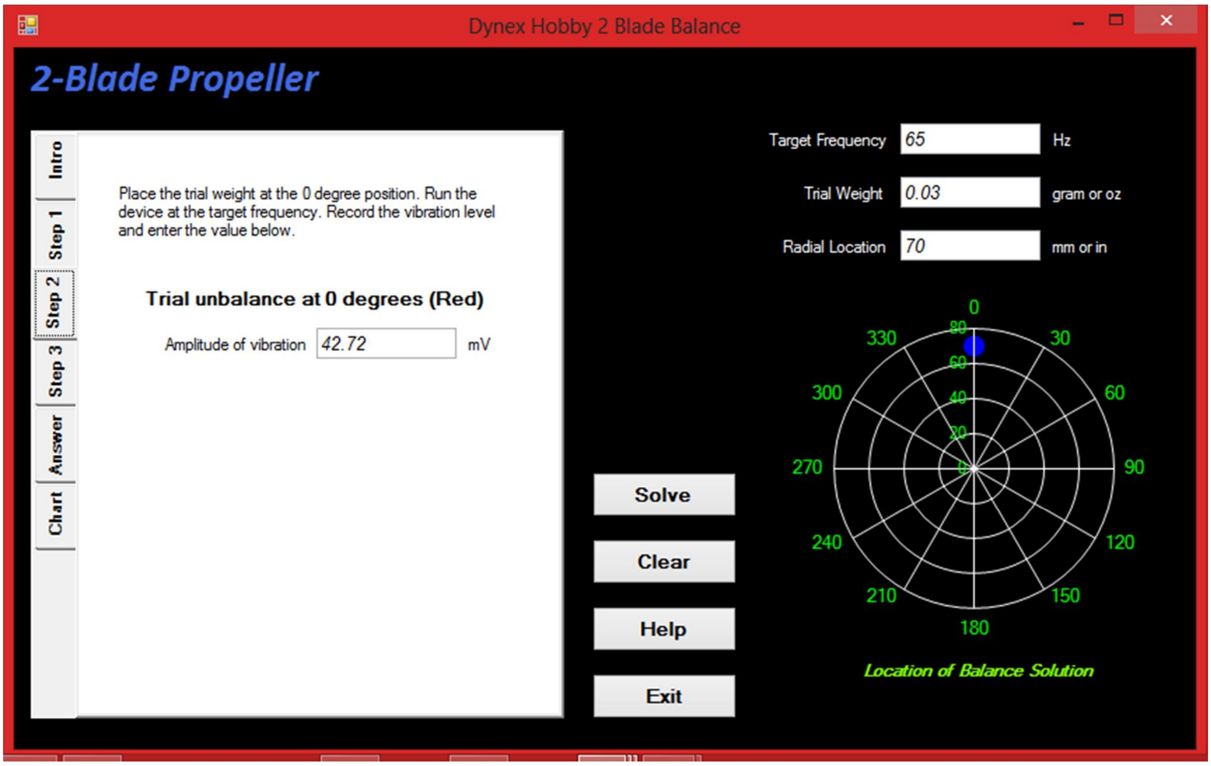




STEP 2 – Trial Unbalance 1

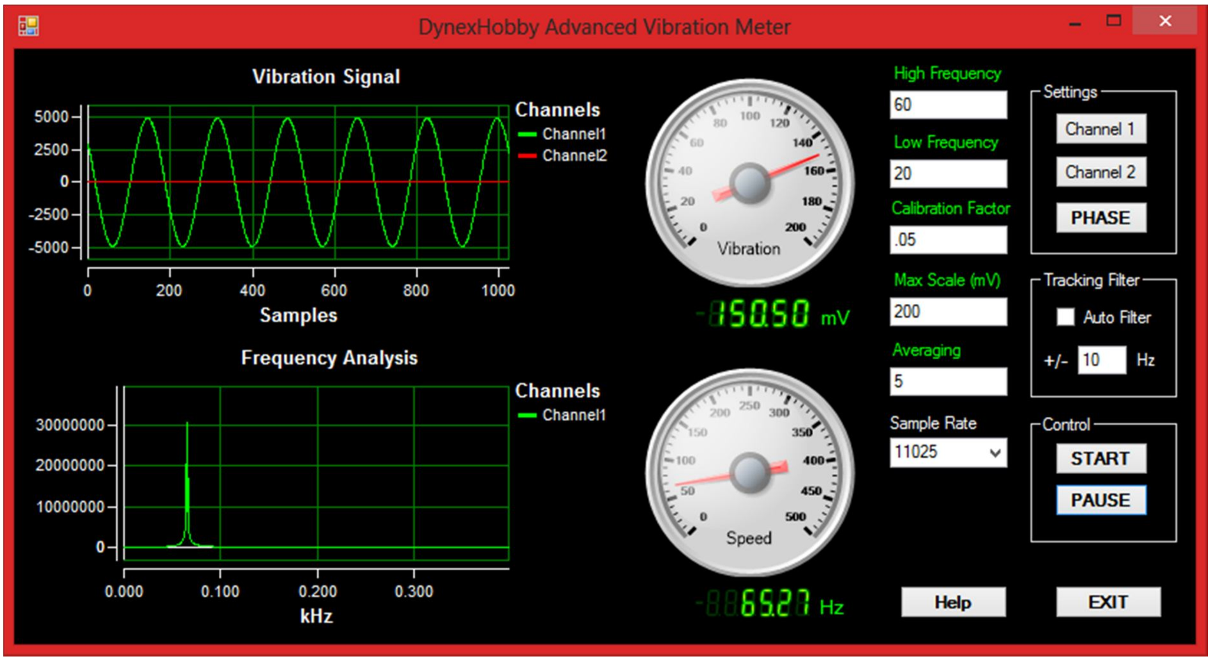
- ✓ Place a trial weight at the **zero** degree position. Example **0.03 gram** at zero degrees positioned **70mm** from axis of rotation.
- ✓ Run device at test speed. Example **65Hz**.
- ✓ Record vibration amplitude. Example **42.72mV**. Enter this value in the **2 Blade Propeller Balance Tool.**

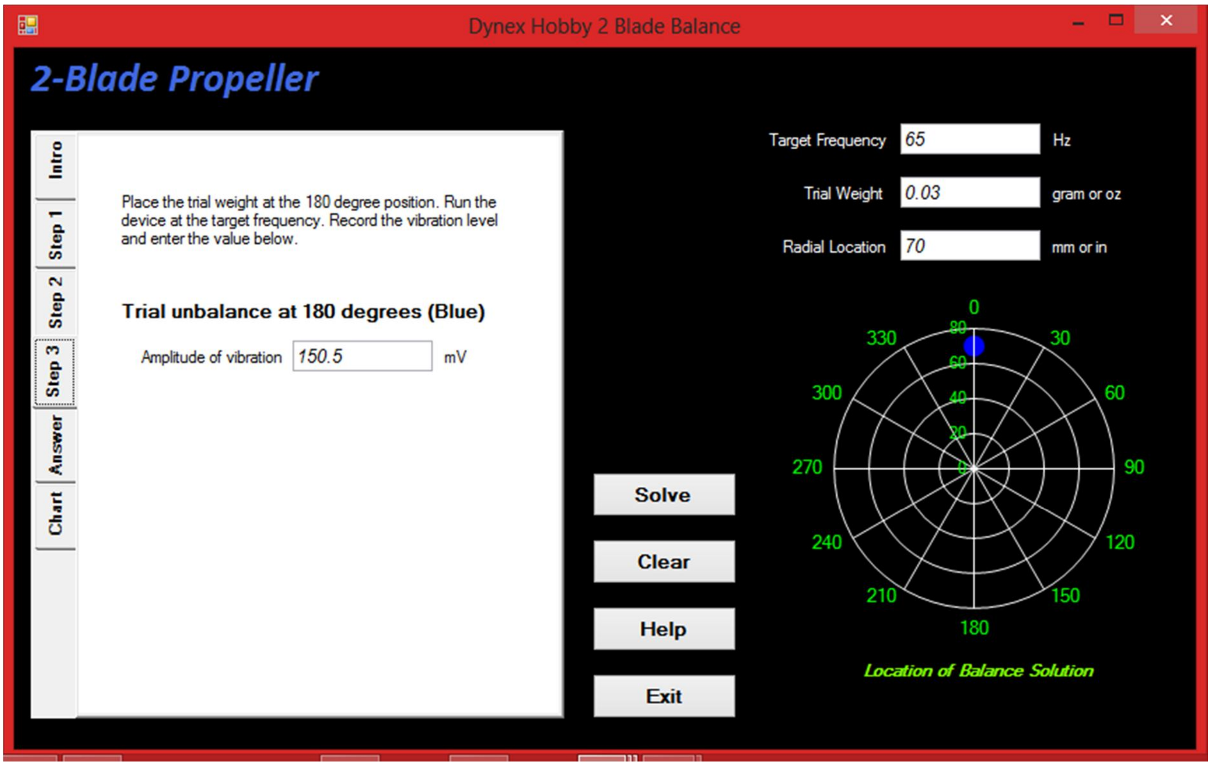




STEP 3 – Trial Unbalance 2

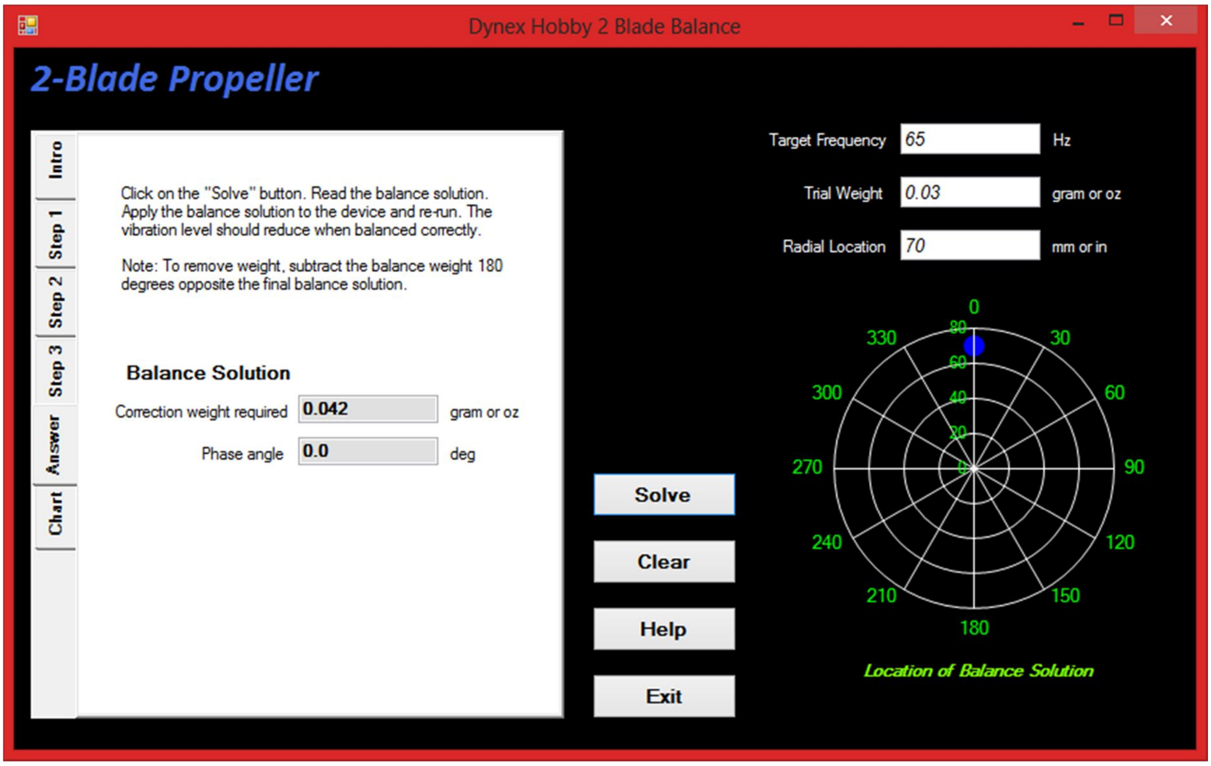
- ✓ Place a trial weight at the **180** degree position. Example **0.03 gram** at **70mm** from axis of rotation.
- ✓ Run device at test speed. Example **65Hz**.
- ✓ Record vibration amplitude. Example **150.5mV**. Enter this value in the **2 Blade Propeller Balance Tool.**





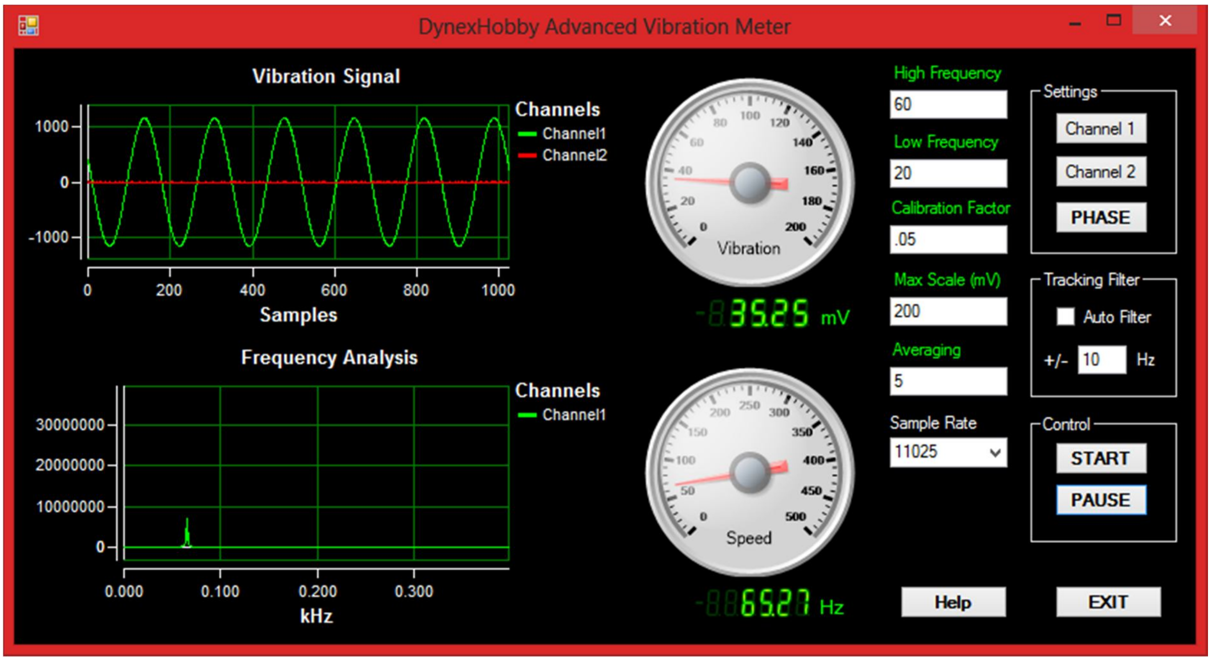
STEP 4 – Determine Required Balance weight

- ✓ Required balance weight is read direct from the **2 Blade Propeller Balance Tool.** Example apply **0.042 gram** at the **0** degree position located **70mm** from axis of rotation.



STEP 5 – Check final balance

- ✓ Run device at test speed. Example **65Hz**.
- ✓ Record vibration amplitude. Example **35mV**. This means the final imbalance is 214% better than the original imbalance. With more effort the imbalance can be reduced much further by altering the balance weight.



CLOCK BALANCE METHOD

When to use this method:

- Generally can be used on most items
- When you want precise balancing with minimal residual balance
- Other methods do not provide adequate results.
- Fine tuning results.

Limitations

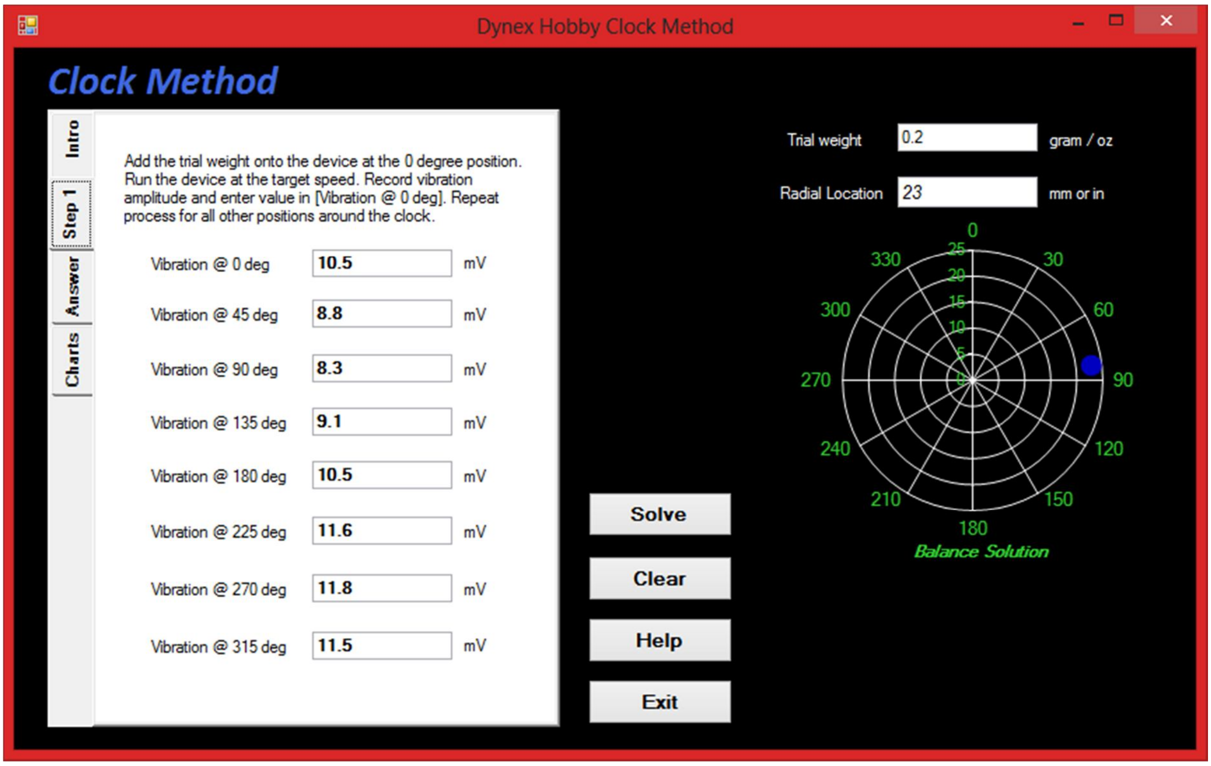
- Excessive vibration beyond Vortex limits.

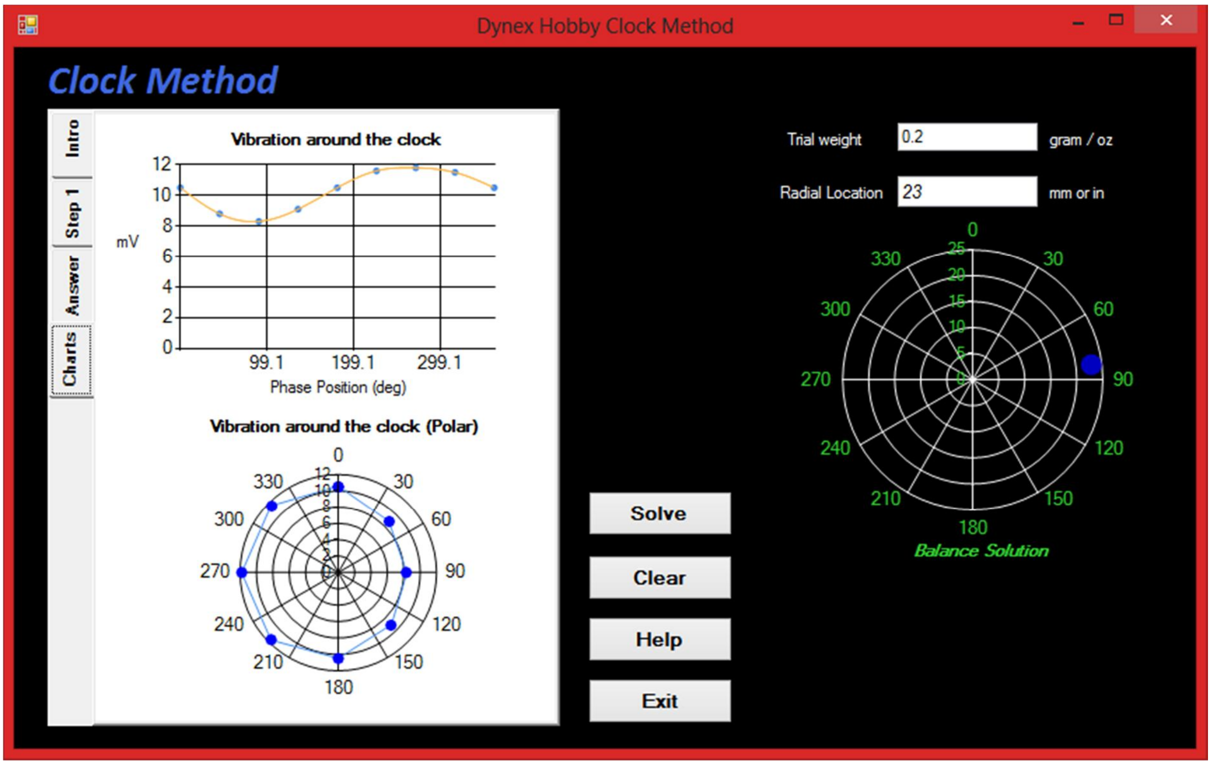
Setup

- ✓ Setup and secure propeller and motor mount to test stand.
- ✓ Attach accelerometer onto motor mount in direction of maximum vibration.
- ✓ Ensure accelerometer is calibrated for mounting location.
- ✓ Connect Vortex to PC.
- ✓ Determine running speed that produces a nice sine wave on the oscilloscope display (away from system natural frequency).

STEP 1 – Trial Unbalance

- ✓ Place a trial weight at the **zero** degree position. Example **0.2 gram** at zero degrees positioned **23mm** from axis of rotation.
- ✓ Run device at test speed. Example **65Hz**.
- ✓ Record vibration amplitude. Example **10.5mV**. Enter this value in the **Clock Balance Tool.**
- ✓ Repeat **Step 2** for all positions around the clock.
- ✓ The tool will display a linear map of the vibration amplitude as well as a polar map. This will help the user visualize the position of the residual mass.





STEP 2 – Determine Required Balance weight

- ✓ Required balance weight is read direct from the **Clock Balance Tool.** Example apply **0.035 gram** at the **82.8** degree position located **23mm** from axis of rotation. The position is shown on the chart at the right hand side of the window.

VIBRATION SPECTRUM ANALYSIS

Introduction

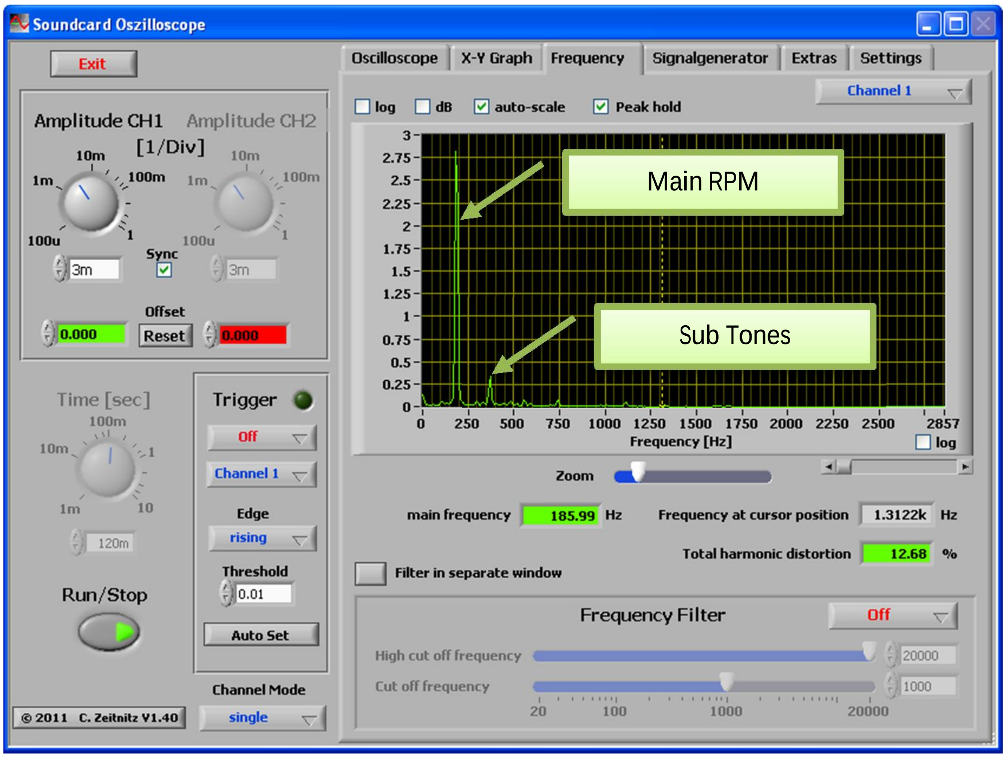
Vortex is capable of analyzing signals in real time. This can easily be performed using oscilloscope software equipped with this feature. Spectrum analysis is typically used as a fault finding tool when determining the source of unusual vibration.

Setup

- ✓ Setup device in mounting frame
- ✓ Ensure adequate spring and dampening is set.
- ✓ Ensure accelerometer is calibrated for mounting location. Remove filter capacitor.
- ✓ Connect Vortex to PC.
- ✓ Switch “Filter” to off. Turn “filter dial” counter-clockwise until it stops.

STEP 1 - Measuring

- ✓ Start rotor and run at constant speed.
- ✓ Switch oscilloscope software to “frequency” analysis.
- ✓ Click on the “peak hold” option to start recording data.

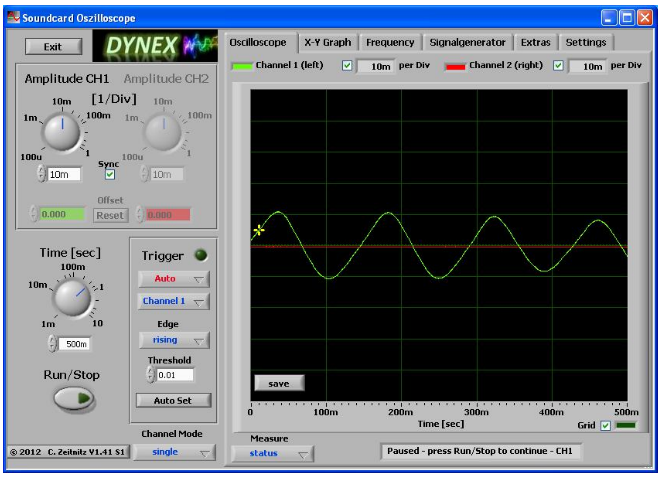


The spectrum analysis holds vast amounts of data of the device under test. The largest peak is normally the running speed of the rotor. Sub tones are typically lower than the main peak. These can be attributed to phenomena such as bearing noise, loose mechanical connections, aerodynamic and lubrication effects.

VORTEX LIMITATIONS

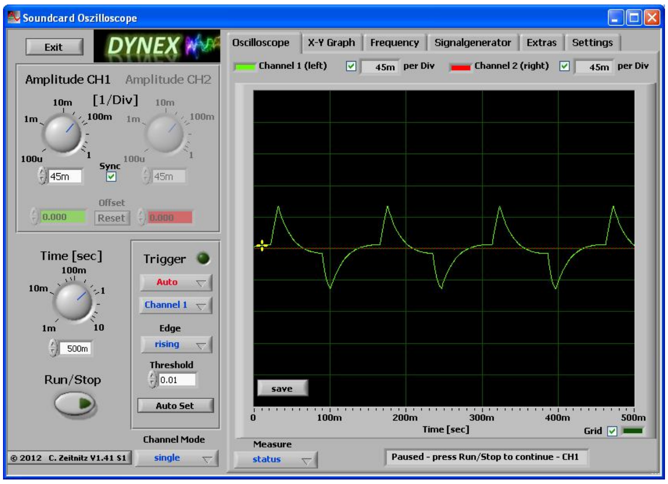
Introduction

Vortex operates by converting vibration into an electrical signal. These signals are conditioned by onboard circuitry and sent to the PC soundcard. A normal signal when filtered will look like the one below.



However when vibration levels exceed Vortex limits, the onboard circuitry will "clamp" the signal down to safe operating limits. This is designed to prevent damage to the PC soundcard.

When a vibration signal reaches the physical limits of Vortex, the signal will appear distorted particularly at the signal peaks when viewed in the oscilloscope. A sample of distortion is shown below. Distortion may also appear as a square wave.



Should the operator experience signal distortion, **immediately** turn down the "Gain" dial until the signal appears as a normal sine wave. If the distortion continues, cease operation of Vortex.

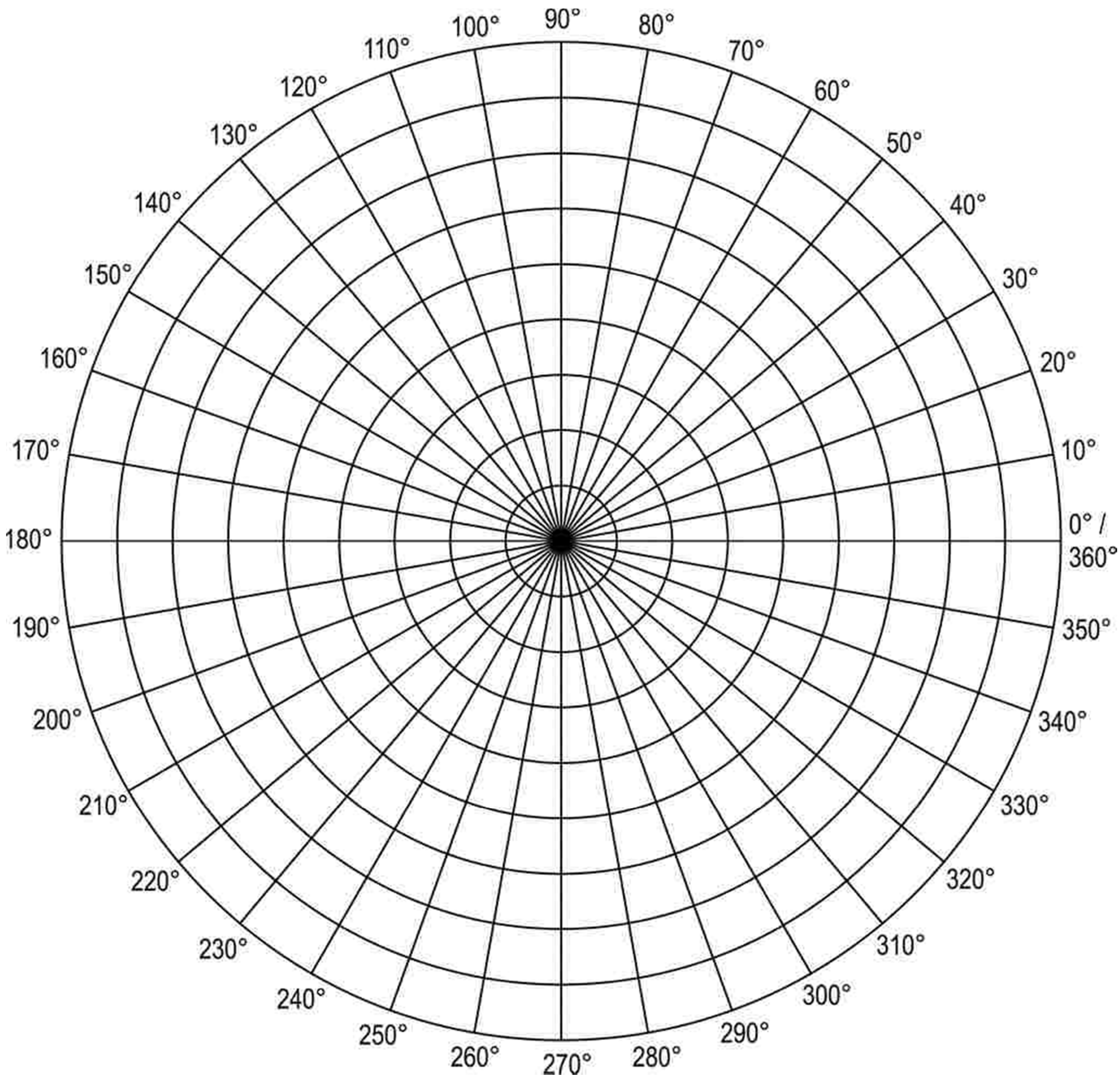
The table below summarizes some common issues observed during test.

Frequency	Cause	Comments
>1/2 × rpm	Oil whirl	Exists in sleeve bearings, change speed, or oil temperature
1 × rpm	Unbalance, eccentric journals	Level is greatest in radial direction Proportional to unbalance
2 × rpm	Mechanical looseness	Look for loose bolts, etc.
1 ×, 2 ×, 3 ×, 4 × rpm	Misalignment of couplings, bearings and bent shaft	Level is greatest in axial direction
1, 2, 3, 4 × rpm of Belts	Bad drive belts	Pulsing amplitude
1, 2, or 3 × frequency of electrical power (usually 50 or 60 Hz)	Electrical ground loops, etc.	Amplitude drops instantly when power turned off
No. of blades × rpm multiples of no. of blades × rpm	Blade frequencies	A high level could mean a stall
Blade frequency $\pm n \times \frac{\text{rpm}}{60}$ $n = 1, 2, 3$	Loose coupling	The sidebands are usually quite a bit lower in level than the blade frequency
No. coupling pins, teeth, or grids × rpm	Failing coupling	Could be due to misalignment, wear, lack of lubrication of coupling
1 × rpm of gear No. gear teeth $\times \frac{\text{rpm}}{60} \times n$ $n = 1, 2, 3, \ldots$	Eccentric pitch circle, tooth errors in gear Poor gear mesh	Could be due to poor meshing, wear of meshing surfaces, resonance of the gear train. Harmonics could be due to skewed axes of rotation.
Mesh frequency $\pm n \times \frac{\text{pinion rpm}}{60}$	Eccentric pinion, pinion shaft not parallel to bull gear shaft, poor pinion support	The more sidebands of high amplitude appear, the greater the severity of the problem
Mesh frequency $\pm n \times \frac{\text{bull gear rpm}}{60}$	Eccentric bull gear, bull gear not parallel to pinion shaft, bull gear shaft deflection	See above
$1/2\ Z f\ [1 + \left(\frac{d}{e}\right) \cos \alpha]$	Spall, inner bearing race	f = rotational speed, Hz d = ball diameter, in e = pitch diam, in x = contact angle, degrees Z = number of balls
$1/2\ Z f\ [1 - \left(\frac{d}{e}\right) \cos \alpha]$	Spall, outer bearing race	See above
$f \left(\frac{e}{d}\right) [1 - \left(\frac{d}{e}\right)^2 \cos^2 \alpha]$	Spall, ball of bearing	See above
$1/2\ f\ [1 - \left(\frac{d}{e}\right) \cos \alpha]$	Cage unbalance	See above

A great source for learning about vibration spectrum analysis can be found at this website,

http://www.vibronurse.com

APPENDIX – STROBE BALANCE SHEET



First run trigger level (O)	
Correction vector length (C)	
Trial weight (W)	
Correction weight = O / C x W	

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